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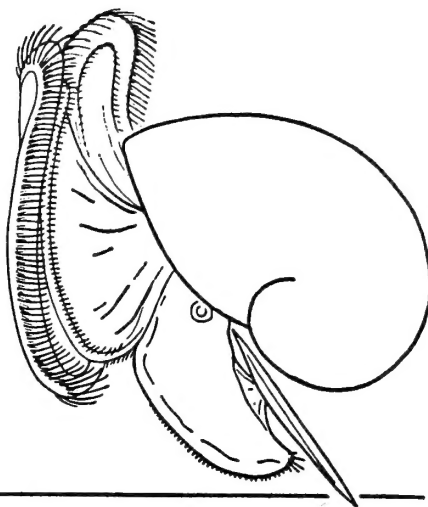


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# THE VELIGER

A Quarterly published by  
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Berkeley, California

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Division of Mollusks  
Sectional Library

## Volume 10

July 1, 1967 to April 1, 1968

## Foreword to Volume 10

With the completion of Volume 10 we have reached a milestone on the road of the development of *The Veliger*. This is, then, an occasion to take stock of the past – to review the accomplishments and to assess the failures.

Of all the goals we had set for ourselves about ten years ago, we think we have attained most: our journal has been accepted on a world-wide basis, as evidenced not only by the ever-increasing number of subscribers and members in all parts of the world, but also by the fact that we receive manuscripts from authors in many lands. Our aim to produce a journal of high quality, not only in content, but also in appearance, has been achieved, we believe, within reason. Two important failures, however, still plague us. The first and, to us, an important one is the fact that we have not succeeded in producing an issue completely free of all typographical errors and this in spite of extraordinary precautions we have taken, and also in spite of the unusual skill brought to the task of proof-reading by Mrs. Jean Cate of Los Angeles. The blame for the remaining errors rests with the editor himself.

The second failure is the one that has plagued us since the first issue – finances. But again, as in the past, we must assume the responsibility for this: we have steadfastly refused to permit this problem to force us into seeking aid through applying for governmental grants. That our situation is not completely untenable is due to the most generous contributions made by a few individuals in the form of many uncounted hours of volunteer labor. Foremost among these volunteers are Mrs. Emily Reid whose artwork continues to lend that extra touch of beauty and attractiveness to our journal; Mrs. Cate, who not only checks every word set in type for correct spelling but also, with the aid of a magnificent malacological library and a sound knowledge of the field itself, often is able to prevent erroneous citations; Mrs. R. Stohler who, through the years, has not only assisted with many menial tasks, such as collating, preparing for mailing, recording and checking and double-checking, but also has encouraged the editor in his desire to avoid asking for governmental assistance.

What measure of success we have had with the development of *The Veliger* is also due to many contributions made in various ways by a large number of persons. If we single out a few for special mention, it is not to imply that the contributions of those not listed were less important. Among those who have assisted the editor with their technical advice are Mr. Armand Lamadrid of Los Angeles, an efficient linotype operator and mechanic as well as a staunch friend; Mr. John Schoen and the late Earl Gustafson of the Printing Department of the University of California in Berkeley have been ever ready with helpful advice, suggestions and real practical assistance.

Another group of men and women who have given and continue to give unstintingly of their talents and time are the members of the Editorial Board who spend many hours reviewing the manuscripts submitted for publication and whose recommendations are the guides for the decisions by the editor. Last – most assuredly not least, the members of the Executive Board of the California Malacozoological Society give generously of their time, talents and substance.

Finally, the craftsmen at the Printing Department, who seem to take special pains to turn out a high quality product deserve to be included in this list.

To all the many individuals, named and unnamed alike, we express our deeply felt gratitude, hoping at the same time to be permitted in the future to continue taking advantage of their knowledge, skills and talents so that *The Veliger* may continue to develop and, hopefully, to become self-supporting at a time not too distant in the future.

Sincerely,  
Your Editor

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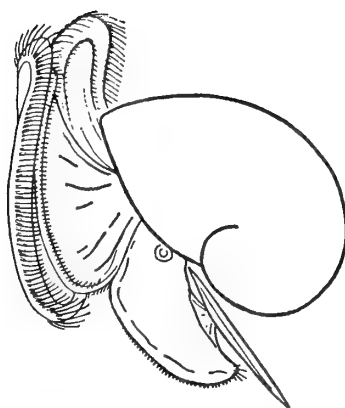
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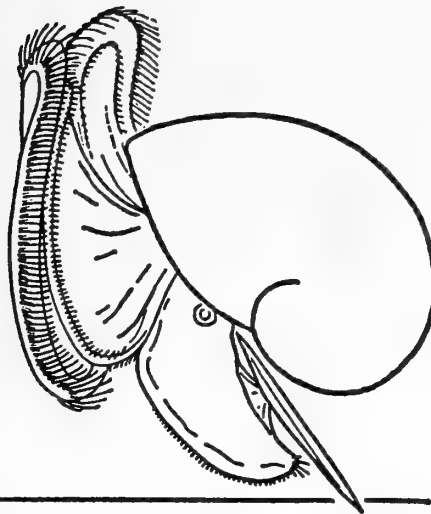




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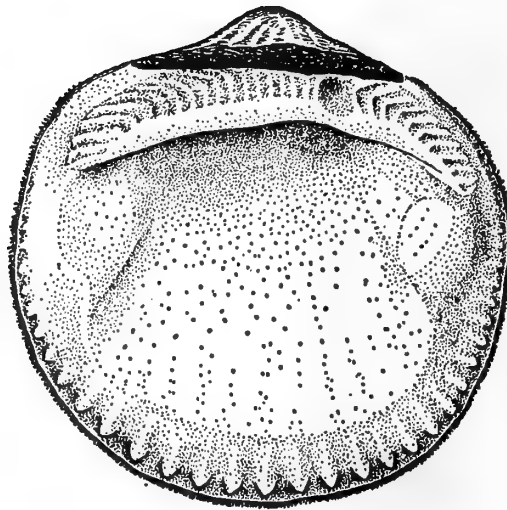
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

**ORDER, Suborder, DIVISION, Subdivision, SECTION,**  
**SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).**  
***New Taxa***

## Two New Species of British Turrids

BY

EDMUND H. SMITH

Department of Zoology, University of Glasgow, and the Marine Station, Millport<sup>1</sup>

(Plate 1; 5 Text figures)

THE PRESENT CLASSIFICATION of the Turridae is based almost entirely on shell characters. The weakness of such a classification, however, has been clearly demonstrated during a recent study of the turrids of the Clyde Sea Area, Scotland in which almost identical shells were found to "house" radically differing animals. Thus, while some specimens of "*Philbertia leufroyi boothi* (SMITH, 1839)" from the Clyde Sea Area possess the usual complement of radula, poison gland and salivary glands, others, almost indistinguishable conchologically, were found without any trace of these structures. A second, apparently undescribed, turrid from the same area was found to lack these structures. It is considered that these findings warrant the creation of a new genus and of two new species.

*Cenodagreutes* E. H. SMITH, gen. nov.

**Type species:** *Cenodagreutes aethus* spec. nov.

The shell characters are similar to those of *Philbertia* (see esp. THIELE, 1931, p. 370), and as in that genus, the operculum is absent. Internally, however, it can be distinguished from *Philbertia*, and probably from all other genera of British turrids (E. H. SMITH, 1967), by the absence of the radula, poison gland, and salivary glands.

**Etymology:** The generic name *Cenodagreutes* is derived from the Greek *κενοδοντις*, toothless, and *αγρευτης*, the hunter, meaning the "toothless hunter", alluding to the lack of radular teeth.

*Cenodagreutes aethus* E. H. SMITH, spec. nov.

(Plate 1, Figures 1 and 2; Text figures 1 to 3)

**Shell:** The shell is small (7 mm in length), fusiform, has a short spire and seven to eight prominently convex whorls.

The nuclear whorls number three and are diagonally decussate. The postnuclear whorls are sculptured with very prominent axial ribs which are crossed by thin, well defined uniformly spaced spiral cords; on the penultimate whorl the axial ribs number 14, the spiral cords 6. The ornamentation consists of very fine axial growth rugae and small pustules covering the depressions between the spiral cords. The suture is fine and there is no sutural shelf. The labial aperture is ovate and the siphonal canal is short and smooth. The sinus is shallow and occupies most of the shoulder. The parietal and columellar calluses are smooth and abruptly marked off from the surface ornamentation. The outer lip is thin.

**Color:** The ground color of the shell is creamy white, the pustules are brilliant white and the spiral cords reddish-brown. Over some of the axial ribs, however, the brown coloration of the cords is absent.

**General appearance:** The foot is a translucent creamy color, flecked on the sides and near the opening of the rhynchodaeum with brilliant opaque white. The siphon is uniformly cream colored.

**Internal anatomy:** The polyembolic proboscis (SMITH, 1967) is much shorter than that of *Philbertia leufroyi boothi* (Text figure 1). There are two projections (br) on the mid-line of the floor of the rhynchodaeum (rh). The two major introvert retractor muscles (rm) send small bundles of fibers into each of the two small projections. The oral opening (oo) is surrounded by a thin circular muscle layer which thickens posteriad around the anterior oesophagus (oc). The epithelium surrounding the oral region and passing posteriorly for a short distance is densely ciliated. The glandular sheath (gs) which encircles the oral opening is short with a few thin muscle strands leading from the fold of the sheath to the wall of the cephalic haemocoel. After the oesophagus passes through the nerve ring (nr) it enlarges; gland cells replace the densely ciliated epithelium found in the anterior

<sup>1</sup> Present address: Pacific Marine Station, Dillon Beach, California 94929.

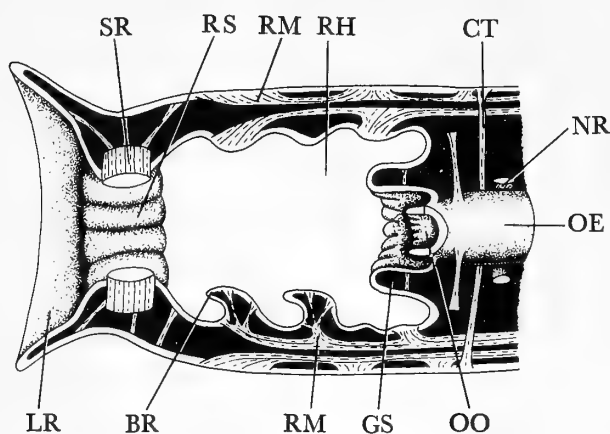


Figure 1

*Cenodagreutes aethus*

Idealized diagram depicting longitudinal section through the rhynchodaeum.

br mid-ventral bumps of the rhynchodaeum  
 ct circumoesophageal tensors  
 lr lip of the rhynchodaeum  
 oo opening of oesophagus  
 rm major retractor muscles of the rhynchodaeum  
 rs rhynchostome  
 sr sphincter of the rhynchostome  
 gs glandular sheath  
 nr nerve ring  
 oe oesophagus  
 rh rhynchodaeum

region. There are no salivary glands, radular sac, or poison gland. The intestine is covered by a thin muscular layer and lined by ciliated cells. There is no anal gland.

Present in the male reproductive system (Text figure 2) is a large vesicula seminalis (vs) and a connective tissue strand (a remnant of the gonopericardial duct, gd) running from the vas deferens (vd) to the pericardial wall (pc). An opening (mo) connects the vas deferens to the mantle cavity and there is a convoluted prostate gland (pg) which opens into a short penis (p).

In the female reproductive system (Text figure 3) the gonadal oviduct (go) is composed of columnar gland cells and surrounded by a thick muscular layer. The renal oviduct (ro) is short, narrow, and enters the albumen gland (al) ventrally. There is no gonopericardial duct. The albumen gland is ciliated throughout with no subepithelial glands. The epithelium of the albumen gland becomes continuous with the posterior part of the capsule gland (cg). There

is no pallial oviduct. A short, constricted muscular duct joins the anterodorsal part of the albumen gland with the ingesting gland (ig) and functions as a receptaculum seminis. The capsule gland has no ventral channel and opens into a small bursa copulatrix (bc). This bursa is muscular with a narrow lumen which opens directly into the capsule gland. The epithelium lining the capsule gland and extending a short way into the bursa is composed of gland cells.

**Type specimens:** The holotype was collected off Farland Point, Isle of Cumbrae, Firth of Clyde, Scotland (Lat.

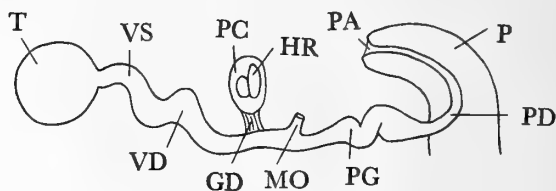


Figure 2

*Cenodagreutes aethus*

Diagrammatic reconstruction from sections, of the male reproductive system.

gd gonopericardial duct  
 mo opening from vas deferens to mantle  
 pa opening of penis  
 pc pericardial wall  
 pd duct from prostate gland  
 vd vas deferens  
 hr heart  
 p penis  
 pg prostate gland  
 t testis  
 vs vesicula seminalis

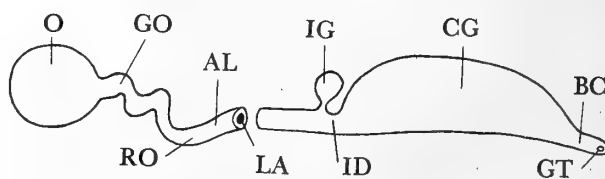


Figure 3

*Cenodagreutes aethus*

Diagrammatic reconstruction from sections, of the female reproductive system.

al albumen gland  
 go gonadal oviduct  
 id duct to ingesting gland  
 la lumen of the albumen gland  
 bc bursa copulatrix  
 cg capsule gland  
 gt genital opening  
 ig ingesting gland  
 ro renal oviduct

## Explanation of Plate 1

Figure 1: *Cenodagreutes aethus*, a view of the shell aperture.

Figure 2: *Cenodagreutes aethus*, a view of the labial sinus.

Figure 3: *Cenodagreutes coccyginus*, a view of the shell aperture.

Figure 4: *Cenodagreutes coccyginus*, a view of the labial sinus.



Figure 1



Figure 2

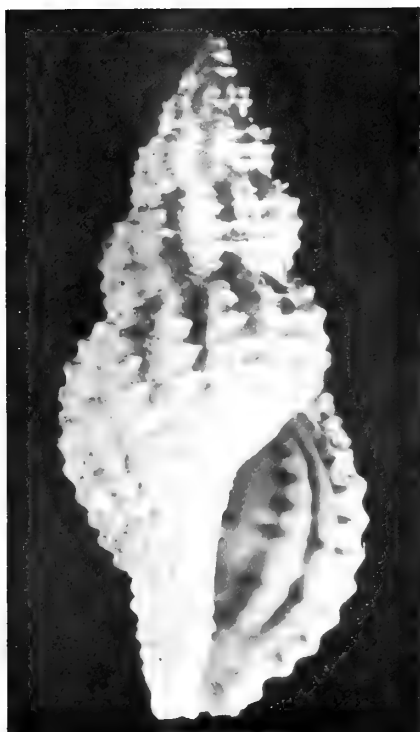


Figure 3

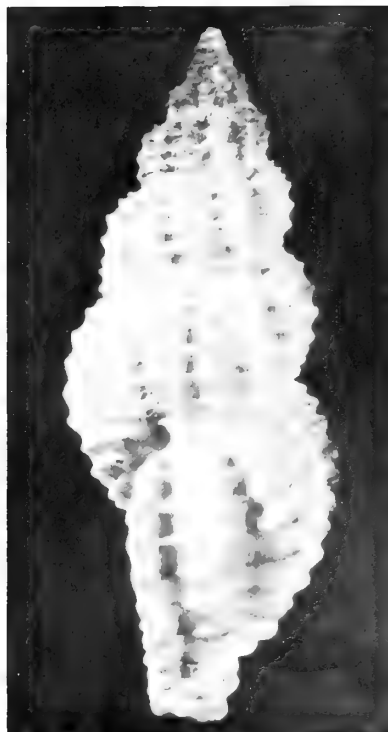


Figure 4



55° 44' 20" N, Long. 4° 57' 30" W) on a bottom of stones and mud in 20 m. The holotype has been serially sectioned and these sections, along with the broken shell, are deposited at the California Academy of Sciences, Department of Invertebrate Zoology, Type number 320. It consists of 4 microscope slides, CAS numbers 338 - 341. A paratype, consisting of an unbroken shell is also deposited at the same institution, Type number 321.

**Etymology:** The specific name *aethus* is derived from the the Greek *αἶθων*, and refers to the red color.

*Cenodagreutes coccyginus* E. H. SMITH, spec. nov.

(Plate 1, Figures 3 and 4; Text figures 4 and 5)

**Shell:** The shell is small (5½ mm in length), fusiform, and has a short spire with seven whorls which are somewhat less convex than in *Cenodagreutes aethus*. The nuclear whorls number three, and are diagonally decussate. The postnuclear whorls are sculptured with very prominent axial ribs which are crossed by thin, well defined and uniformly spaced spiral cords; on the penultimate whorl the axial ribs number 14, the spiral cords 6. The ornamentation consists of very fine axial growth rugae and fine granules, in contrast to the pustules of *C. aethus*, which cover the depressions between the axial ribs and spiral cords. The suture is fine and there is no sutural shelf. The labial aperture is ovate and the siphonal canal short and

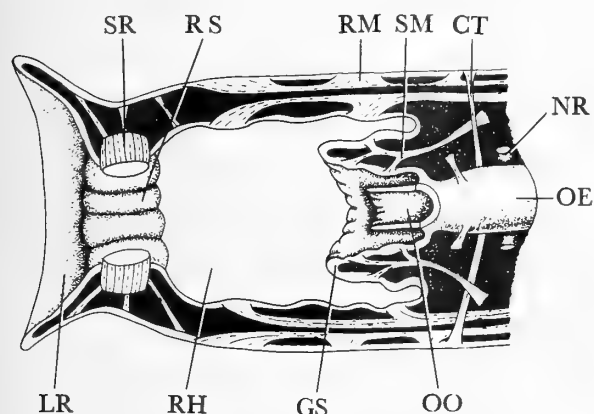


Figure 4

*Cenodagreutes coccyginus*

Idealized diagram depicting longitudinal section through the rhynchodaeum.

- |    |   |    |                  |
|----|---|----|------------------|
| ct | circumoesophageal tensors                   | gs | glandular sheath |
| lr | lip of the rhynchodaeum                     | nr | nerve ring       |
| oo | opening of the oesophagus                   | oe | oesophagus       |
| rm | major retractor muscles of the rhynchodaeum | rh | rhynchodaeum     |
| rs | rhynchostome                                | sm | sheath muscles   |
| sr | sphincter of the rhynchostome               |    |                  |

smooth. The labial sinus is distinct when compared to *C. aethus* and occupies most of the shoulder. The parietal and columellar calluses are smooth and abruptly marked off from the surface ornamentation. The outer lip is thicker than in *C. aethus*.

**Color:** The ground color of the shell is creamy white with alternating dark reddish-brown spiral lines which are broken occasionally by opaque white or yellowish zones.

**General appearance:** The foot is translucent creamy white, sometimes tinged with purple and covered with opaque white spots on the sides. The siphon is uniformly white.

**Internal anatomy:** As in *Cenodagreutes aethus* a polyembolic proboscis is present (Text figure 4). The projections on the floor of the rhynchodaeum (rh) are absent and the oral opening (oo) is surrounded by a very thick muscle layer. In contrast to *C. aethus* the epithelium surrounding the oral region and passing posteriorly for a short distance is cuticular. The glandular sheath (gs) which encircles the oral opening is long with well developed muscle strands (ms) leading from the fold of the sheath to the wall of the cephalic haemocoel. The oesophagus extends into the oral sheath for some distance forming "lips". After the oesophagus passes through the nerve ring (nr), it enlarges, as in *C. aethus*, with gland

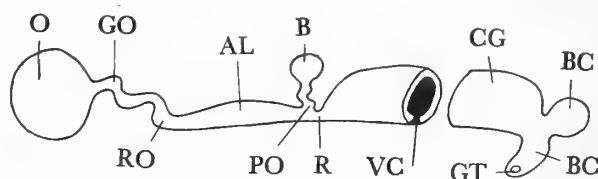


Figure 5

*Cenodagreutes coccyginus*

Diagrammatic reconstruction from sections, of the female reproductive system.

- |    |                  |    |   |
|----|------------------|----|---|
| al | albumen gland    | b  | distal bulb of the receptaculum seminis |
| bc | bursa copulatrix | cg | capsule gland                           |
| go | gonadal oviduct  | gt | genital opening                         |
| o  | ovary            | po | pallial oviduct                         |
| ro | renal oviduct    | r  | receptaculum seminis                    |
|    |                  | vc | ventral channel                         |

cells replacing the cuticular epithelium of the more anterior region. There are no salivary glands, radular sac, or poison gland. The intestine is ciliated and surrounded by a thick muscular layer. There is a long, thin anal gland which follows the intestine for some distance, opening into its lumen near the anus.

Only female specimens of this very rare turrid have been found. The female system (Text figure 5) is similar to that of *Cenodagreutes aethus* with the following exceptions. There is a pallial oviduct (po) between the

albumen gland (al) and capsule gland (cg). No sperm were found in the small distal bulb (b) of the receptaculum seminis nor was there any evidence of sperm ingestion. The capsule gland has a ventral channel (vc). The bursa copulatrix (bc) is much larger than that of *C. aethus* with the bulb forming the distal end of the bursa and lying at the anterior end of the capsule gland. This enlargement forms a sperm filled sac. It is not lined by glandular epithelium but by one composed of densely ciliated cells.

**Type specimens:** The holotype was collected off Tan Buoy between Great Cumbrae and Little Cumbrae Islands, Firth of Clyde, Scotland (Lat. 55° 44' 20" N, Long. 4° 57' 30" W) on a sandy shell bottom in 17 m. The holotype has been serially sectioned and these sections, along with the broken shell, are deposited at the California Academy of Sciences, Department of Invertebrate Zoology, Type number 322. It consists of 5 microscope slides, CAS numbers 342 - 346. A paratype, consisting of an unbroken shell is also deposited at the same institution, Type number 323.

**Etymology:** The specific name *coccyginus* is derived from the Greek *κοκκυγινος*, and refers to the purple color.

**Discussion:** *Cenodagreutes coccyginus* is most easily distinguished externally from *C. aethus* by its darker overall shell color and by having granules which are finer than the pustules of *C. aethus* covering the depression between the axial ribs. Internally, the major differences lie in the alimentary tract and the reproductive system. In *C. aethus* as contrasted to *C. coccyginus* the projections along the floor of the rhynchodaeum are absent, the glandular sheath is long, a cuticular epithelium lines the anterior part of the oesophagus and a long, thin anal gland lies along the intestine near the anus. The reproductive system of *C. aethus* differs from that of *C. coccyginus* by having a pallial oviduct along with an ingesting gland, a ventral channel in the capsule gland and a large anteriorly placed sperm sac which is part of the bursa copulatrix.

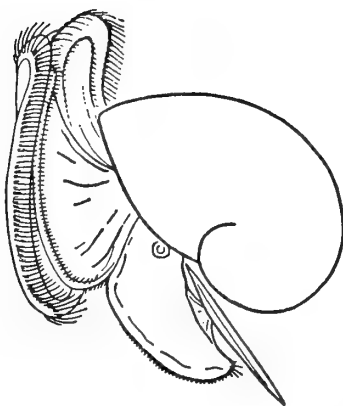
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# The Radula of *Zierliana woldemarii* (KIENER, 1839)

BY

JEAN M. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(3 Text figures)

THE GENUS *Zierliana* GRAY, 1847 is quite different morphologically from most other mitrid forms, except for the presence of typical columellar folds. Some of its species have such un-mitrid characters as prominent denticles on the labrum, a distinct posterior notch or canal, and in some cases – as in the type species, for example – a clearly atypical shape for a mitrid. Some of the species have whorls that are smooth as in Mitrinae [*Zierliana anthracina* (REEVE, 1844), ? *Z. quoyi* (DESHAYES, 1844)], or weakly spirally ribbed [*Z. woldemarii* (KIENER, 1839)]. At least one form [*Z. aethiops* (REEVE, 1845)] has vexillid axial ribbing on the body whorl, while another has a combination of both axial and spiral ribs [*Z. ziervogeliana* (GMELIN, 1791)]. All of these factors have led to a certain amount of conjecture as to the correct systematic position of the genus.

For some time I had tried to secure preserved specimens for further study of the radula and soft parts, but without success. There are only a few species in the genus, probably not more than six or seven; most of these seem relatively rare in collections and are seldom seen preserved with animal intact. Recently my mention of this

taxonomic problem led Mrs. Virginia Orr Maes of the Academy of Natural Sciences of Philadelphia to extract and mount the radula of a specimen of *Zierliana woldemarii* from the Academy's collection (Text figure 1). This



Figure 2

*Zierliana ziervogeliana* (GMELIN, 1791), type species

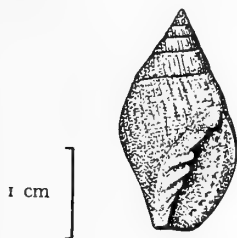


Figure 1

*Zierliana woldemarii* (KIENER, 1839)

species is quite similar in form to the type species, *Z. ziervogeliana* (Text figure 2), and it can probably be safely assumed that the radulae of both species would be relatively similar also. Mrs. Maes sent me the slide she had prepared, together with the two halves of the shell from which the radula had been extracted. I am grateful to her for her quick and practical response to my casual mention of the problem.

As may readily be seen from the drawing (Text figure 3), the radula of *Zierliana woldemarii* is definitely of vexillid type, with a multicuspoid rachidian and sickle-shaped lateral teeth, similar to the radulae of *Vexillum cadaverosum* (REEVE, 1844), *V. exasperatum* (GMELIN, 1791) and *V. semifasciatum* (LAMARCK, 1811). However, it is proportionately a good deal smaller, and possesses rounded rachidians, whereas the cusps of the other species are sharply pointed, as illustrated by CERNOHORSKY (1966, p. 119).

It would seem, therefore, that this evidence supports the previously tentative placement of the genus *Zierliana*

in the Vexillinae. Its morphological characters are distinct enough from other vexillid forms, however, to warrant retaining *Zierliana* as a full genus apart from those forms having closely similar radulae.

The accompanying text figures were drawn by Mrs. Emily Reid of the Veliger staff.

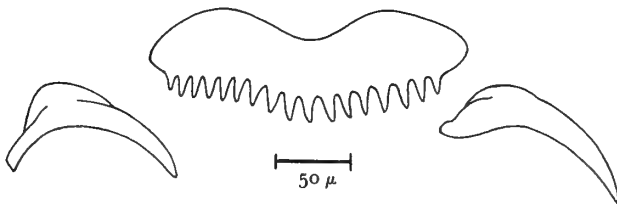


Figure 3

*Zierliana woldemarii* (KIENER, 1839)

Radula. Preparation by V. O. Maes, ANSP.

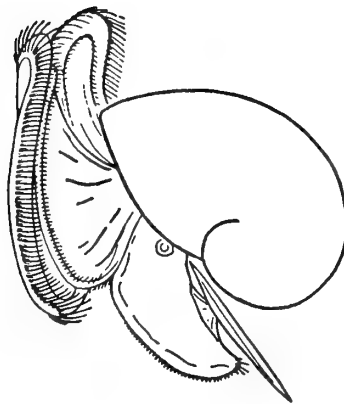
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KIENER, LOUIS CHARLES

1839. *Spécies général et iconographie des coquilles vivantes; Mitra*. Rousseau, Paris; 4: 1 - 120; pls. 1 - 34



# A New Terebrid Species with Check List of Terebridae from the Red Sea

(Mollusca : Gastropoda)

BY

TWILA BRATCHER<sup>1</sup>

AND

R. D. BURCH<sup>2</sup>

(Plate 2)

SINCE 1962 THE JUNIOR AUTHOR has been studying the terebrid fauna of the Gulf of Akabar on the Red Sea with the cooperation of Mr. D. C. Insall, an ardent local collector. The check list here included and the description of a new species are the result of that study. The majority of the specimens examined was taken by shore collecting and diving. A few additional specimens were collected from the dredged sea bottom when the Port of Eilat, Israel was being constructed.

Eilat, on the Gulf of Akabar (listed on many maps as the Gulf of Aqaba) is located at 29° 32' 20" North and 34° 57' 00" East. This is an area where the desert sands and the water of the gulf meet, and there is little, if any, rise and fall of tide. The fauna examined is entirely Indo-Pacific and is at the northern end of its range. Nothing seems to have been published on the Recent terebrid species of the Red Sea.

Specimens of each species listed here remain in the collection of Mr. Insall, and it is our understanding that his collection will be open to students of conchology. Arrangements for examining the collection may be made by writing Mr. D. C. Insall at P.O. Box 3079, Haifa, Israel.

The following list is not presumed to be all-inclusive, but it does contain all the species of *Terebra* encountered by Mr. Insall and included in his own collections and in those of other collectors of his area.

*Terebra* BRUGUIÈRE, 1789

(*Triplostephanus*) DALL, 1908

*Terebra* (*Triplostephanus*) *insalli* BRATCHER & BURCH,  
spec. nov.

(Plate 2, Figures 1 to 3)

**Shell:** Medium sized, pale beige, slender and elongated with 21 narrow, slightly concave whorls divided by a convex sutural band of white. A subsutural band of pearly tubercles joins the sutural band. Balance of the whorl sculptured by transverse lines adjacent to the sutural and subsutural bands plus two additional weaker spiral lines crossed by axial lines more numerous than the tubercles on the subsutural band. This gives the effect of three corded bands of small almost squared, somewhat flattened nodes, the posterior being the most prominent. Sculpture remarkably consistent from the early whorls to the body whorl on which the third row from the subsutural band becomes a row of protruding nodes at the periphery. These spiral lines are broken by somewhat obsolete axial lines. Body whorl short. Aperture small, ovate, ending in a short recurved canal. Columella short, recurved, with one microscopic plication, laminated. Length 59.9 mm, width 8.0 mm.

**Holotype:** California Academy of Sciences, Department of Geology, Type collection no. 12946 (Plate 2, Figures 1 and 3).

**Paratypes:** Paratype no. 1: R. D. Burch coll. no. 589; Length 59.1 mm, Width 8.0 mm; nucleus missing.

<sup>1</sup> 8121 Mulholland Terrace, Hollywood, California 90046

<sup>2</sup> P.O. Box 133, Downey, California 90241

Paratype no. 2: T. Bratcher coll. no. 30001; L. 30.9 mm, W. 4.9 mm; nucleus intact (Plate 2, Figure 2).

Paratype no. 3: Insall coll. no. 7/11G; L. 59.8 mm, W. 7.6 mm; nucleus missing.

Paratype no. 4: Insall coll. no. 7/12; L. 82.3 mm; W. 8.8 mm; apex missing.

Paratype no. 5: Conchological collection, Stanford University; L. 50.2 mm, W. 6.9 mm; apex missing.

Paratype no. 6: Museum of Comparative Zoology, Harvard University; L. 50.3 mm, W. 7.1 mm; half of nucleus missing.

Paratype no. 7: Santa Barbara Museum of Natural History coll. no. 23729; L. 50.8 mm, W. 7.4 mm; apex missing.

Paratype no. 8: British Museum (Natural History) collection; L. 52.4 mm, W. 7.9 mm; apex missing.

**Type Locality:** All specimens were collected on the Gulf of Akabar, Red Sea, 29° 32' 20" N, 34° 57' 00" E. Only two specimens of the type lot were live taken. Paratype no. 3 was collected at South Beach in 10 feet of water on sand bottom, and Paratype no. 7 was taken at Coral Beach in 6 m of water, both by divers.

## DISCUSSION

This species may be separated easily from the three to which it bears greatest resemblance: *Terebra cumingii* DESHAYES, 1857 (Plate 2, Figure 4), *T. triseriata* GRAY, 1834 (Plate 2, Figure 5), and *T. jenningsi* R. D. BURCH, 1965 (Plate 2, Figure 6). The whorls are more numerous and much narrower than in *T. cumingii* but with about the same apical angle. Also the sculpture of *T. insalli* is coarser and with fewer spiral striae than in that of *T. cumingii*. The sculpture of *T. insalli*, though similar to that of *T. triseriata*, has a more beaded look between the sutural bands. The whorls of *T. insalli* are about the same width as those of *T. triseriata*. *Terebra triseriata* is a more slender shell with a more acute apical angle. There is less resemblance to *T. jenningsi* which has quite smooth sculpture, wider whorls, and a longer, less recurved canal. Some of

the paratypes exhibit a double row of incised spiral lines between the first and second row of nodulated cords posterior to the suture.

For the sake of expediency the following subgenera are provisionally accepted. Much work on the generic structure of this family is needed.

### Genus:

*Terebra* BRUGUIÈRE, 1789. Encycl. Méth., Vers, vol. 1, pl. xv. Type species: *Buccinum subulatum* LINNAEUS, 1767.

### Subgenera:

(*Abretiella*) BARTSCH, 1923, Nautilus, vol. 37 (2): 61 to 63. Type species: *Terebra cerithina* LAMARCK, 1822.

(*Decorihastula*) OYAMA, 1961, Venus, vol. 21 (2): 185. Type species: *Terebra affinis* GRAY, 1834.

(*Dimidiacus*) IREDALE, 1929, Austral. Zool., vol. 5: 341. Type species: *Terebra cingulifera* LAMARCK, 1822.

(*Oxymeris*) DALL, 1903, Proc. U. S. Nat. Mus., vol. 26: 951. Type species: *Buccinum maculatum* LINNAEUS, 1758.

(*Perirhoe*) DALL, 1908, Nautilus, vol. 21: 124. Type species: *Terebra circumcincta* DESHAYES, 1857.

(*Strioterebrum*) SACCO, 1891, Moll. terr. Terz. Pied. e Lig. pt. 10, p. 33. Type species: *Terebra basteroti* NYST, 1843.

(*Subula*) SCHUMACHER, 1817, Ess. Nouv. Syst., p. 233. Type species: *Buccinum dimidiatum* LINNAEUS, 1758.

(*Triplostephanus*) DALL, 1908, Nautilus, vol. 21: 124. Type species: *Terebra triseriata* GRAY, 1834.

### Genus:

*Hastula* H. & A. ADAMS, 1853. Gen. Rec. moll., vol. 1: 225. Type species: *Buccinum strigilatum* LINNAEUS, 1758.

### Subgenus:

(*Hastulina*) OYAMA, 1961, Venus, vol. 21 (2): 183-184. Type species: *Terebra casta* HINDS, 1843.

## Explanation of Plate 2

Figure 1: *Terebra insalli* BRATCHER & BURCH, spec. nov. Holotype, C. A. S. No. 12946 (x 1½)

Figure 2: *Terebra insalli*. Paratype No. 2. Bratcher collection (x 4½)

Figure 3: Same shell as Figure 1, body whorl (x 2.8)

Figure 4: *Terebra cumingii* DESHAYES, 1857. Body whorl. Burch collection (x 2.8)

Figure 5: *Terebra triseriata* GRAY, 1834. Body whorl. Burch collection (x 2.8)

Figure 6: *Terebra jenningsi* BURCH, 1965. Paratype No. 34. Body whorl. Burch collection (x 2.8)

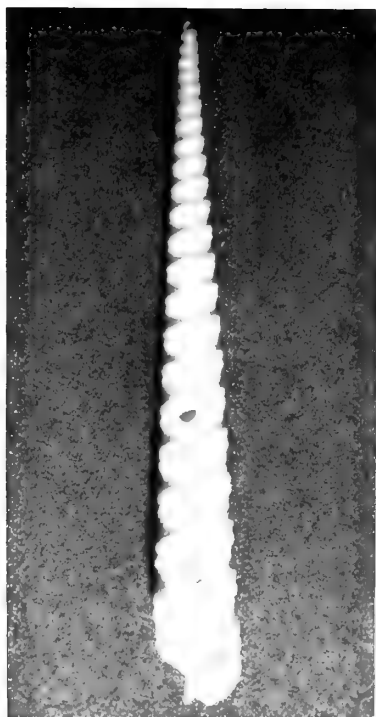


Figure 1

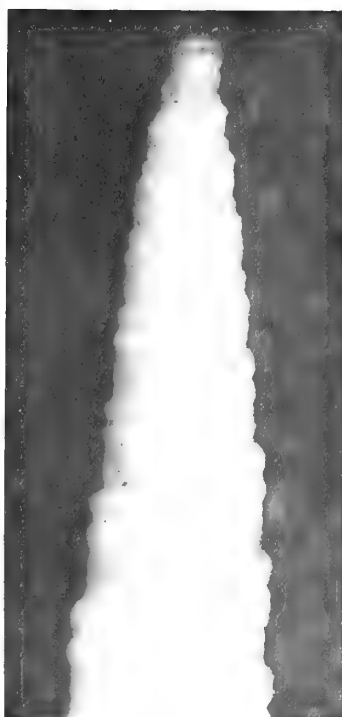


Figure 2

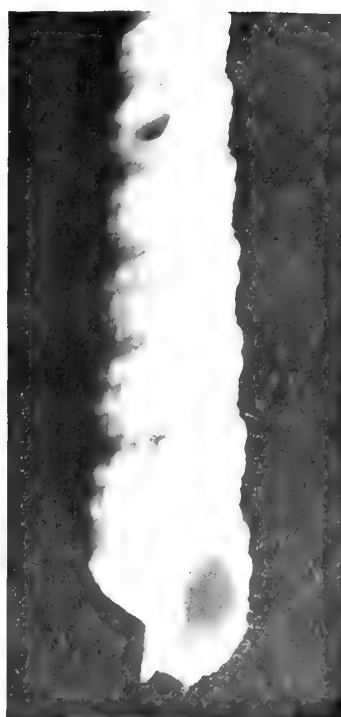


Figure 3



Figure 4

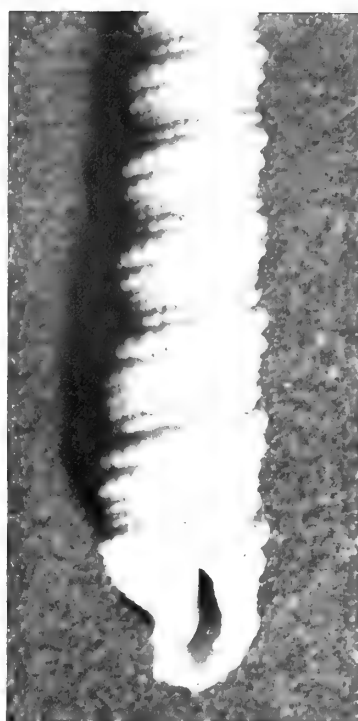


Figure 5

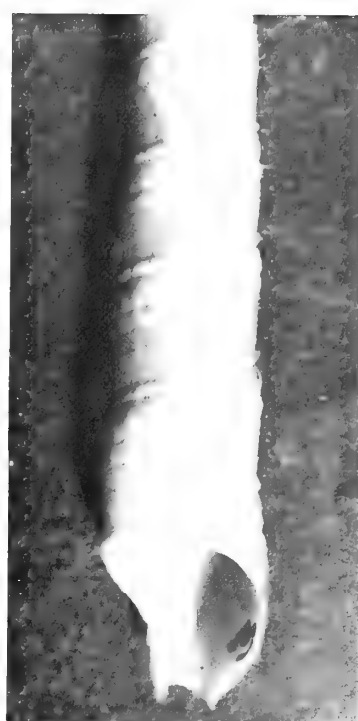


Figure 6



A Check List of Terebridae  
from the Gulf of Akabar, Red Sea

- Terebra* (*Decorihastula*) *affinis* GRAY, 1844. Proc. Zool. Soc. London f. 1843: 60; fig. HINDS in SOWERBY, Thes. Conch., 1844, plt. 44, fig. 78. (*non* TURTON, 1832).
- T. (Decorihastula) columellaris* HINDS, 1844. Proc. Zool. Soc. London f. 1843: 151; fig. HINDS in SOWERBY, Thes. Conch. 1844, plt. 44, fig. 77.
- T. (Decorihastula) flavofasciata* PILSBRY, 1921, Proc. Acad. Nat. Sci. Philadelphia 69: 306; plt. 2, fig. 3.
- T. (Decorihastula) nebulosa* SOWERBY, 1825, Tank. Cat. append., p. 25 (*non* KIENER, 1839; *non* LOROIS, 1859).
- T. (Triplostephanus) insalli* BRATCHER & BURCH, spec. nov.
- T. (Dimidiacus) albomarginata* DESHAYES, 1859. Proc. Zool. Soc. London 1859: 314, no. 212; fig. REEVE, Conch. Icon. 1860, plt. 15, fig. 65.
- T. (Dimidiacus) amanda* HINDS, 1844. Proc. Zool. Soc. London, 1843: 154; fig. HINDS in SOWERBY, 1844, p. 166, no. 46; plt. 45, fig. 100.
- T. (Dimidiacus) consobrina* DESHAYES, 1857. Journ. Conchyl. 6: 72; plt. 3, fig. 3.
- T. (Subula) areolata* (LINK, 1806). Besch. Nat. Samml. Univ. Rostock, p. 128; fig. CHEMNITZ, Conch. Cab., 1780 (4), plt. 153, fig. 1441 and plt. 154, fig. 1443. (*non* ADAMS & REEVE, 1850).
- T. (Subula) argus* HINDS, 1844. Proc. Zool. Soc. London f. 1843: 160; fig. HINDS in SOWERBY, Thes. Conch. 1844, plt. 23, fig. 64.
- T. (Subula) dimidiata* (LINNAEUS, 1758), Syst. Nat., ed. 10, p. 741, no. 420; fig. KIENER, Icon. Coq. Viv., 1839, plt. 2, figs. 2, 2a.
- T. (Perirhoe) babylonia* LAMARCK, 1822. Anim. s. Vert. 7: 287, no. 9; fig. KIENER, Icon. Coq. Viv., 1839, plt. 14 (in part), fig. 35 only.

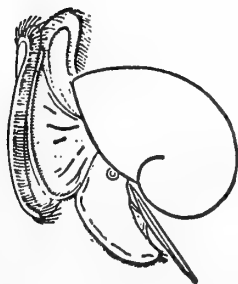
- T. (Abretiella) cerithina* LAMARCK, 1822, Anim. s. Vert. 7: 288, no. 15; fig. KIENER, Icon. Coq. Viv., 1839, plt. 11, fig. 25.
- T. (Oxymoris) crenulata* (LINNAEUS, 1758), Syst. Nat., ed. 10, p. 741, no. 416; fig. KIENER, Icon. Coq. Viv., 1839, plt. 5, figs. 9, 9a.
- T. (Oxymoris) maculata* (LINNAEUS, 1758), Syst. Nat., ed. 10, p. 741, no. 415; fig. KIENER, Icon. Coq. Viv., 1839, plt. 1, fig. 1.
- T. (Strioterebrum) textilis* HINDS, 1844. Proc. Zool. Soc. London f. 1843: 156; fig. HINDS in SOWERBY, Thes. Conch., 1844, plt. 44, fig. 73.
- Hastula (Hastulina) casta* (HINDS, 1844), Proc. Zool. Soc. London f. 1843: 156; fig. HINDS in SOWERBY, Thes. Conch. 1844, plt. 44, fig. 84.

#### ACKNOWLEDGMENT

We wish to express our thanks and appreciation to Mr. D. C. Insall for his generous cooperation in sending specimens for this study and for donating type specimens for distribution.

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- GRAY, JOHN EDWARD  
1834. Untitled. [*Terebra*] Proc. Zool. Soc. London, Part II (1834): 50-63 (50-56: 26 Sept.; 57-63: 25 Nov. 1834)



# The Retention of Lamellibranch Larvae in the Niantic Estuary<sup>1</sup>

BY

JOHNES K. MOORE<sup>2</sup>

AND

NELSON MARSHALL

Graduate School of Oceanography  
University of Rhode Island, Kingston, Rhode Island 02881

(1 Map)

MARSHALL & WHEELER (1965) found that phytoplankton were most abundant in the inner stretches of the Niantic estuary; *i. e.*, on the upriver side of the shoals that set off the estuarine basin from the outer Bay (see Map). Phytoplankton concentrations, somewhat less than those occurring in the basin and commonly different in composition, were also found in the Bay, while numbers generally decreased over the shoals. Conditions favoring reproduction in the inner estuary, particularly for the dinoflagellates so numerous there, plus the general lack of dispersal from this semi-enclosed area may account for much of the abundance observed in the basin area.

Data gathered by the senior author on the dispersal of common planktonic lamellibranch larvae show little or nothing when examined for correlations with data on light, depth, salinity and stage of tide. However, on noting the distributions of each species on early dates of the summer spawning season, it is clear that the larvae are consistently most abundant in the basin and upriver stations in spite of extreme irregularities in other respects (Table 1). In this way the larval distributions grossly parallel those of the phytoplankton. For these planktonic larvae it seems unlikely that this distribution is the direct result of a concentrated spawning activity in the inner estuary. The spawning bay scallops, *Aequipecten irradians*, are concentrated on the shoals. The spawning oysters, *Crassostrea virginica*, are scattered on the intertidal rocks throughout the estuary. The shipworm, *Teredo*, is ubiquitous but may be most abundant just inshore from the

inlet where there are many docks and pilings. The minute pelecypod identified as *Mysella (Rochefortia) planulata* is thought to be ubiquitous, judging from observations of PHELPS (1964) on a nearby estuary.

MARSHALL & WHEELER (1965) suggested that there might be a differential tidal effect with the flood being more effective than the ebb in the transport of phytoplankton across the shoals. This may be even more significant in the distribution of the planktonic larvae observed and perhaps for holoplankton as well. At the beginning of the flood less than a foot of water covers the shoals. On the flooding tide, waters of relatively high salinities come in from the Bay, cross the shoals and apparently move up estuary along the bottom. With the ebb, surface waters from the basin cross the shoals and move seaward but may tend to remain near the surface. Waters in the Bay, semi-enclosed by headlands, are not immediately swept from the area, so these surface waters may return on the following flood. This simple effect should carry plankton well into the estuary and tend to keep them there. It would tend to be operative irrespective of the vertical movements of the plankton unless they were strongly grouped toward the surface.

The flushing of the estuary tends to counter the hydrographic effect just described. Using runoff data from U. S. Geological Survey Water supply records, it is calculated, with the method of KETCHUM (1951), that 25 days are required for water entering from the tributaries to reach the Bay during times of low runoff such as characterize the spawning period. This does not seem strong enough to counter a tidal mechanism but it may be sufficient to account for the numbers of larvae in the Bay late in the summer.

<sup>1</sup> From work partially supported by Contract AT(30-1)2678 with the Atomic Energy Commission and by the National Science Foundation.

<sup>2</sup> Present address: Salem State College, Salem, Massachusetts 01970

Table 1

The number of lamellibranch larvae per m<sup>3</sup> as sampled at four stations along the axis of the Niantic estuary during the Summer 1963. See Map for station locations<sup>3</sup>.

Date	<i>Mysella planulata</i> (STIMPSON, 1851)			<i>Teredo navalis</i> LINNAEUS, 1758			<i>Crassostrea virginica</i> (GMELIN, 1791)			<i>Aequipecten irradians</i> (LAMARCK, 1819)		
	Bay	Shoals	Basin and Upriver	Bay	Shoals	Basin and Upriver	Bay	Shoals	Basin and Upriver	Bay	Shoals	Basin and Upriver
10 June	4		422	2		39	0		7	0		0
14 June	6	0	710	6	0	62	0	0	1	0	0	7
21 June	2	232	650	6	0	18	0	0	0	0	0	2
1 July	4	32	1416	24	0	62	6	4	9	2	4	6916
8 July	2	88	2222	6	12	36	0	0	11	0	0	37
15 July	54	124	9542	10	0	39	0	0	6	0	0	9
22 July	6	440	2218	56	60	39	4	4	6	0	4	22
29 July	154	304	764	22	180	56	4	20	15	2	0	21
6 August	160	112	244	143	16	10	12	16	23	0	8	0
12 August	84	148	690	42	60	41	32	72	169	0	32	31
15 August	36	52	472	46	64	74	20	56	188	14	20	59
26 August	22	0	95	74	4	39	4	0	4	8	0	546
3 September	58	24	31	64	12	33	16	0	5	0	0	17
18 September	10	4	18	4	0	5	0	0	0	0	0	0

<sup>3</sup> Samples from both the surface and off the bottom were taken at the Bay, Basin and Upriver stations. Since differences did not follow significant patterns they are averaged in this presentation. For the same reason Basin and Upriver data are averaged.

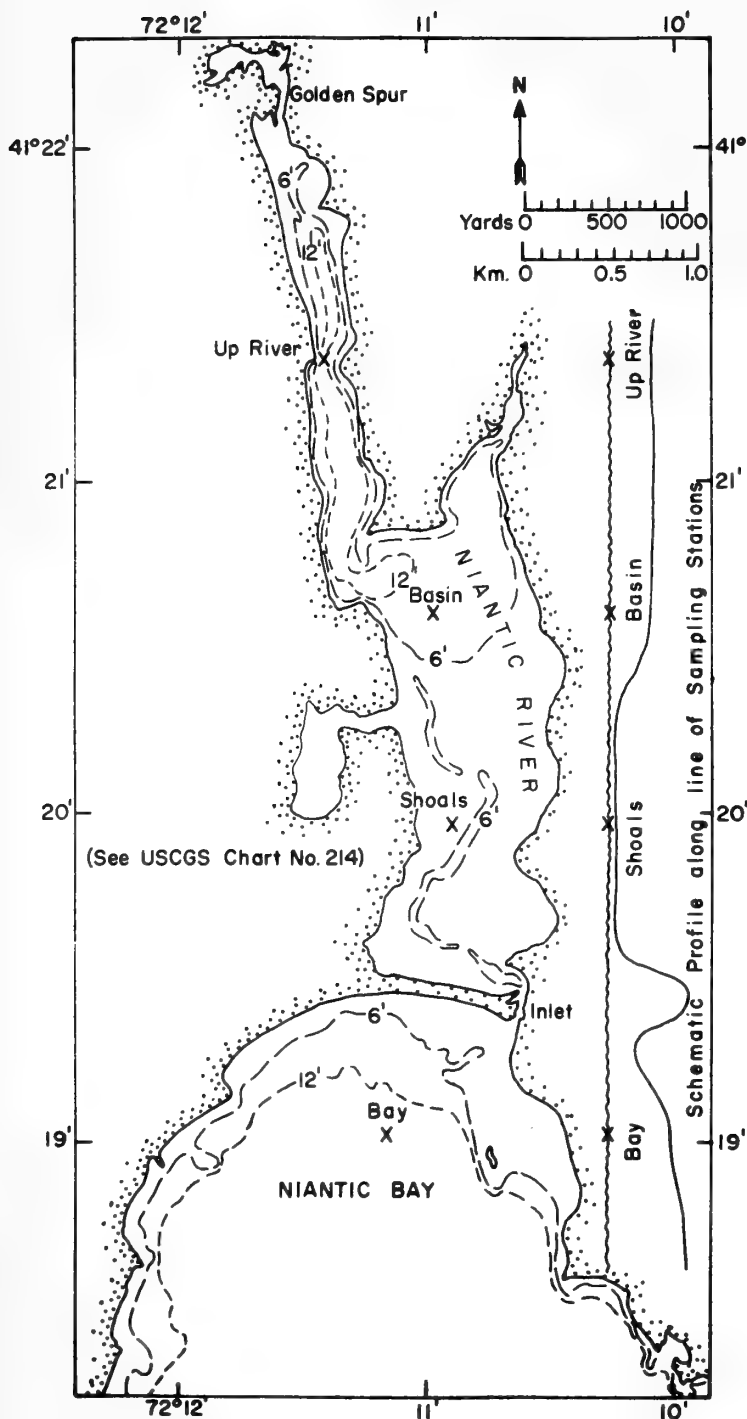


Table 2

$\Sigma\tau$  values as observed along the axis of the Niantic estuary during the lamellibranch larvae sampling, Summer 1963. For each date and station the upper reading is for the upper depth, the lower reading for the lower depths. See Map for station locations and approximate total depths.

Date	Station			
	Bay	Shoals	Basin	Upriver
14 June	21.528	19.738	16.505	16.209
	22.279		21.523	21.257
21 June	21.282	21.705	20.173	18.699
	22.052		21.151	21.489
1 July	20.063	18.973	18.074	18.166
	21.408		20.317	20.477
8 July	21.224	21.324	20.261	19.171
	21.900		21.032	21.185
15 July	20.888	20.256	20.211	19.346
	21.604		20.856	20.932
22 July	21.528	21.509	19.176	18.138
	21.922		21.039	21.003
29 July	20.292	19.106	18.895	17.941
	21.429		20.306	20.429
6 Aug.	21.022	20.628	19.500	18.672
	21.446		20.241	20.358
12 Aug.	20.632	19.837	20.269	19.748
	21.560		20.712	20.844
15 Aug.	21.355	20.349	20.517	19.724
	21.672		21.079	21.022
26 Aug.	21.782	21.011	20.207	20.308
	22.044		20.462	21.017
3 Sept.	21.464	21.494	21.042	20.567
	22.643		21.384	21.451
18 Sept.	22.301	22.272	21.833	21.611
	22.458		22.211	22.254

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## The Cowries of the Ryukyu Islands

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 3; 2 Maps)

### INTRODUCTION

IN ANY DISCUSSION of the Cypraeidae of the Ryukyu Islands it would seem well to include a brief description of this semi-remote, curving chain of approximately 70 islands, for the area comprises roughly a 900 mile long continuous link between the Philippine and Japanese faunal regions.

These Islands have been known by various names. The Japanese refer to them as the Ryukyu Retto; they also are known as the Luchu or Loochoo Group; but, perhaps more correctly, they should be referred to as the Nansei or Ryukyu Islands. They form a natural broken land arc linking the Japanese island of Kyushu with Taiwan (formerly Formosa). In these islands are three important subdivisions: the Amami, the Sakishima, and the Okinawa groups. Altogether they represent an exposed land mass of approximately 847 square miles.

The sovereignty of the Ryukyus has changed many times. From a Chinese protectorate in 1372, successively, this island group became subsidiary to both China and Japan about 1451, eventually falling deeper under Japanese influence in 1609, then finally coming under full control of that country in 1879. As a result of World War II the island group became subject in 1945 to the United States military government. Civil government was returned to the inhabitants in 1951; in 1953 the Amami Group was returned to Japan; custody of Okinawa, the largest island, remains still with the United States.

Most of the field work upon which this report is based was carried out on Okinawa, which is about 65 miles long and approximately 3 to 10 miles wide, forming an important land barrier between the comparatively shallow East China Sea and the deeper Philippine Sea. The island chain lies in a northeast-southwest attitude, approximately 26° 30' North Longitude and 128° 00' East Latitude.

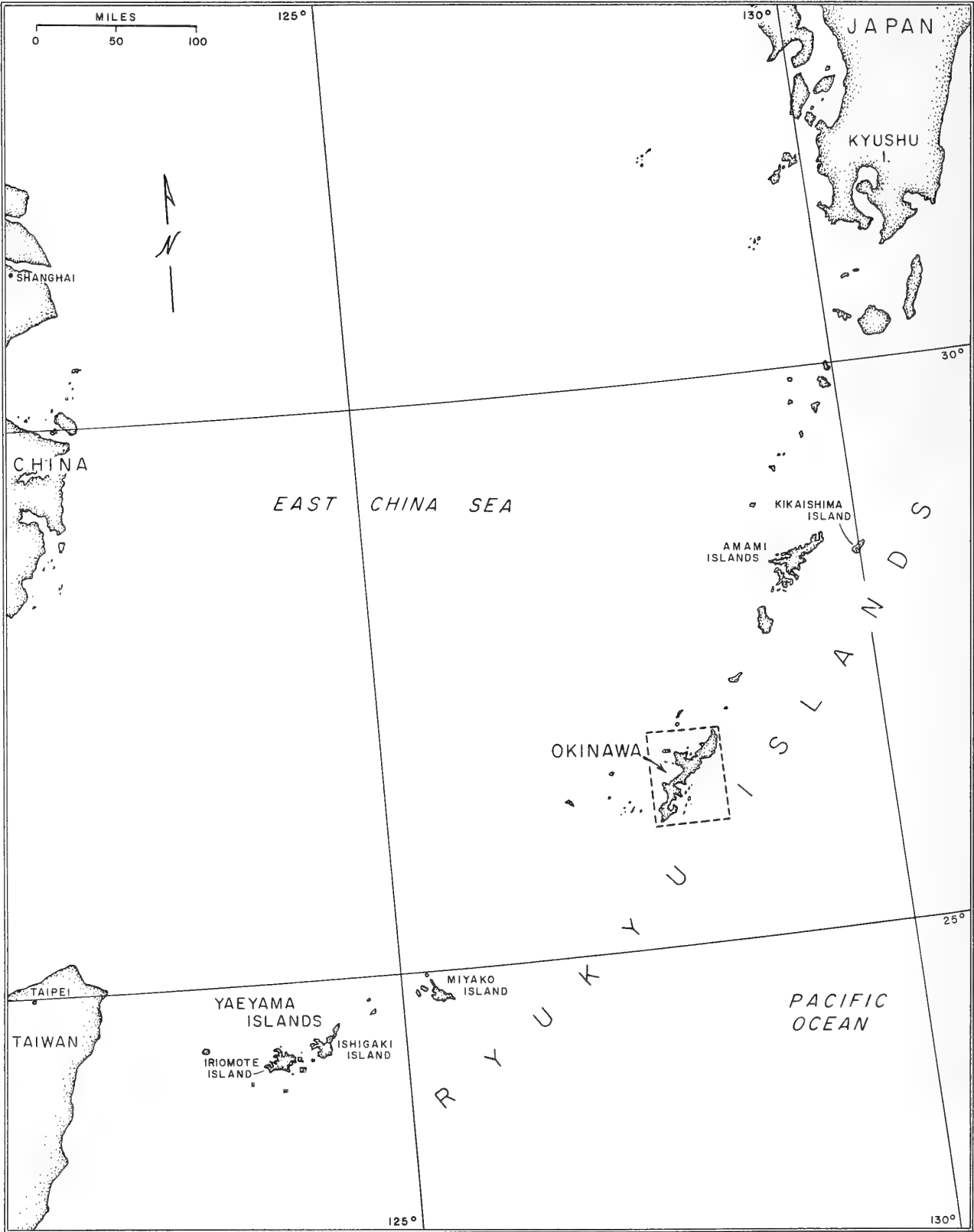
I have examined many specimens of the numerous cowrie species from this area and can find very little, if

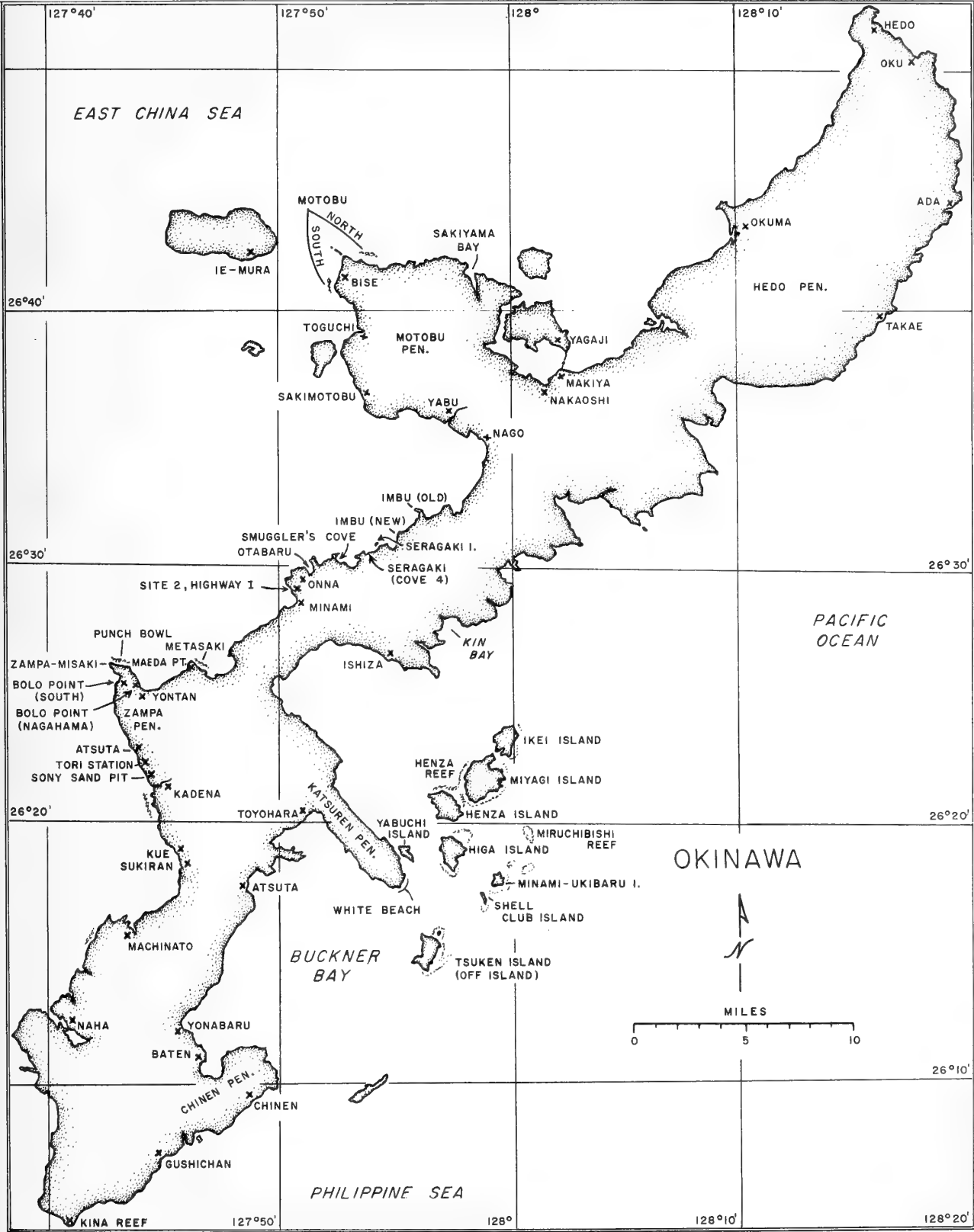
any, differences in color and form as compared with the same species in the Philippine fauna. The shells are indeed strikingly similar in nearly every respect. Perhaps the most obvious differences are that some species are less abundant in the Ryukyus and the depth ranges seem to be more shallow in the northern islands.

Despite its proximity to the Japanese Archipelago the island chain remains a separate ecological entity, and appears to be a transitional area for many of the east Asian cypraeids. Species that are quite common in the Philippines appear here as scarce or decidedly uncommon, even disappearing from the fauna; others appearing only infrequently, then becoming more abundant in the more northern Japanese islands. It should be mentioned that in the northern Japanese islands new species have been discovered fairly recently [such as *Schilderia langfordi* (KURODA, 1938), *S. teramachii* (KURODA, 1938), and *Erosaria guttata azumai* SCHILDER, 1960] some of which may eventually be found in Ryukyu waters.

With a study of the Philippine cowries recently concluded, I am impressed by how closely the shells of the two regions appear to resemble one another morphologically. For this reason I have referred for illustrations to appropriate figures in some of my earlier papers such as CATE, 1965, 1966. The reader is also referred to the latter paper for a comparison of certain similar species, such as *Bistolida pallidula*, *B. interrupta*; *Pustularia cicercula*, *P. bistrinotata mediocris*, *P. tetsuakii*, *P. globulus*; *Bistolida kieneri depriesteri*, *B. hirundo neglecta*, *B. ursellus*.

This study, which has been underway more or less interruptedly for nearly 15 years, will furnish collectors with an authentic modern list of the Ryukyu Cypraeidae. It cannot be considered the final word about cowries in these waters, however, but only the beginning, a basis for future field work and discovery. Listed here are all the species presently known to be living in these waters, all recently collected and substantiated, and now on deposit in various Okinawan collections or in that of the author.





## ECOLOGICAL NOTES

Because of the lack of convenient access to many other islands, collections and reports have been, for the most part, confined to the island of Okinawa, with only an occasional reference to the other Ryukyu islands. Like cowries from most localities, they are found living in coral, under rocks, on sandy flats, and in muddy exposures, usually here, however, in from 4 to 10 feet of water. The distribution for each species in different localities is noted; in few instances have they been of common occurrence.

So that present knowledge of the cowrie populations may not be lost, it is important to record the known species and their distribution in these islands; especially is this true at Okinawa. Great changes are taking place in many of the intertidal and adjacent marine areas because of extensive dredging operations, many sewage systems emptying into the critical offshore waters, and shoreline land fills that are destroying large sections of the natural habitat; further, large quantities of sand and coral are being removed to be made into building material – thereby eliminating sand flats and underwater habitats; and finally, and far from the least, native Okinawans have become conscious of the commercial value of their mollusk fauna, selling the shells to the military personnel. They collect indiscriminately, unintentionally destroying habitats and most of the sea life within their reach.

It would therefore seem of interest to mention the present physical appearance of some of the most important collecting areas (see Maps): – 1/ Machinato is a reef, most accessible at a minus tide; – 2/ Kue is an area of sandy flats and coral tide pools protected from turbulent outer water by reefs that are exposed at low tide; – 3/ Kadena is noted for its coral reef collecting; – 4/ Zampa-Misaki is the general collecting area at the end of the Zampa peninsula. Land's end is known as Bolo Point, and northeast of the point is the Punch Bowl, an area that is exposed at a good minus tide. It should be noted that the entire Zampa region has a very rough sea exposure. – 5/ Onna has important reefs on which *Cypraea* can be found; there are two main collecting areas there, one just south of town, the other to the north. Still further north, Otobaru, Smuggler's Cove, New and Old Imbu (Inbu) are successively important collecting stations. – 6/ Yagaji Island used to be an excellent area for collecting *Cypraea*, especially near the bridge that approaches from Makiya, but a tidal wave of great magnitude a few years ago destroyed the original bridge and disrupted much of the shoreline; since then the molluscan fauna has not returned. – 7/ The northeastern coastline from Takae to Oku is very rocky and mostly inaccessible.

Hedo, at the north end of the peninsula of the same name has been the scene of very limited collecting; the most outstanding species from there is *Ovatipsa chinensis chinensis* (GMELIN, 1791). – 8/ Off the east-central coast of Okinawa is an old Coast Guard station on Ikei Island; nearby are the conchologically important Henza and Miyagi Islands. Between them impressive sand flats are exposed at low tide, and likewise a rocky reef becomes accessible on the east side of Miyagi. It is in this rocky area that the only specimen of *Adusta onyx onyx* (LINNAEUS, 1758) was found. – 9/ Baten was at one time a very productive collecting station. To this day large quantities of dead shells litter the area everywhere, possibly evidence of the extensive dredging operations that have taken place since World War II. There remains, however, now a fine, flat expanse of mud, with the fauna there unknown at present. – 10/ Further south from here are Chinen and Gushichan where many species of *Cypraea* can be found. These are important habitats, and consist of sand, rock, and a limited reef area. Since the southern third of Okinawa is the most densely populated part of the island, it is to be expected that the shore in this area will be most heavily worked over. This is especially true because of the local concentration of military personnel; in their effort to find relaxation they go to the beach to picnic and collect shells, and consequently the tidal areas are denuded of most molluscan life; however, just beyond the intertidal zone, in deeper water, many cowries can still be found.

## EARLIER LITERATURE ON THE AREA

KURODA (1960) appears to have contributed the first checklist of mollusks of the Okinawa Islands. In addition to members of other families listed, he recorded 63 species of *Cypraea* (*l.c.*, pp. 21-23; pl. 3), including two new species, *Notadusta katsuae* and *Bistolida luchuana*. Of those mentioned 57 appear to be valid, some seem misidentified and others species unverified in these waters. It is the purpose of this paper to list only those valid species we have been able to substantiate as currently living in Ryukyu waters.

The late Lloyd E. Berry of Los Angeles probably was the originator of this work with the Ryukyu cowries. In 1952 he received his first specimens from Mrs. Anita Scott, then of Okinawa, and he started to accumulate many of the shells used in this study. It was at this time that I joined Mr. Berry in this work. Later Mr. Berry died, Mrs. Scott returned to the United States, and, for lack of additional material, the project was set aside.

However, in more recent years Bernice and Ernest Albert, Peter Way, and Barbara Keily, all of Okinawa, have joined in the field work to confirm the localities and to substantiate the species, thus assisting me in bringing this study to a close. The decision to 'close' here is arbitrary, for the work can never stop.

During November 1966 I had the opportunity to visit Okinawa. Through the kindness of the just mentioned friends I was able to examine their shell collections and determine the probable population density of a given species from the quantities noted in each instance, as well as to collect at several of the areas listed here and to observe many of the cowrie species in their native habitats.

### ACKNOWLEDGMENTS

The success of such a report as this depends upon the interest, integrity, enthusiasm, and hard work of many individuals. I have mentioned the contributions of Lloyd Berry and Anita Scott; I must now acknowledge those whose field work has been the final word in the completion of this paper: Bernice and Ernest Albert, Peter Way and Barbara Keily — to them all I give heartfelt thanks. To Emily Reid who drew the excellent maps, and to others who have helped in many unseen ways I also express my appreciation. To Jean Cate goes my deep gratitude for continual encouragement and understanding.

### A Summary of Ryukyu Cowrie Species from Selected Localities

#### ZAMPA-MISAKI (BOLO POINT)

*Mauritia (Leporicypraea) mappa mappa*  
*Mauritia (Arabica) arabica asiatica*  
*Mauritia (Arabica) maculifera*  
*Mauritia (Arabica) scurra indica*  
*Talparia talpa talpa*  
*Cypraea (Lyncina) argus argus*  
*Cypraea (Lyncina) lynx vanelli*  
*Cypraea (Lyncina) vitellus vitellus*  
*Cypraea (Lyncina) carneola carneola*  
*Luria (Basilitrona) isabella rumphii*  
*Monetaria (Ornamentaria) annulus annulus*  
*Erosaria (Ravitronea) labrolineata labrolineata*  
*Erosaria (Ravitronea) cernica ogasawarenensis*  
*Erosaria (Ravitronea) helvola helvola*  
*Erosaria (Ravitronea) caputserpentis caputserpentis*  
*Erosaria (Erosaria) poraria scarabaeus*  
*Erosaria (Erosaria) erosa phagedaina*

*Erosaria (Erosaria) miliaris miliaris*  
*Erronea (Erronea) erronea erronea*  
*Erronea (Erronea) caurica caurica*  
*Erronea (Melicerona) felina pauciguttata*  
*Purpuradusta fimbriata marmorata*  
*Bistolida (Blasicrura) pallidula pallidula*  
*Bistolida (Blasicrura) teres teres*  
*Cribraria (Ovatipsa) chinensis chinensis*  
*Cribraria (Cribraria) cribraria orientalis*

#### HENZA-MIYAGI

*Mauritia (Arabica) arabica asiatica*  
*Mauritia (Arabica) scurra indica*  
*Monetaria (Monetaria) moneta rhomboides*  
*Erosaria (Ravitronea) labrolineata labrolineata*  
*Erosaria (Ravitronea) helvola helvola*  
*Erosaria (Ravitronea) caputserpentis caputserpentis*  
*Erosaria (Erosaria) erosa phagedaina*  
*Erronea (Adusta) onyx onyx*  
*Erronea (Erronea) erronea erronea*  
*Purpuradusta gracilis japonica*  
*Purpuradusta fimbriata marmorata*

#### SMUGGLER'S COVE

*Cypraea (Lyncina) carneola carneola*  
*Palmadusta clandestina moniliaris*  
*Bistolida (Blasicrura) teres teres*  
*Bistolida (Bistolida) stolidula stolidula*  
*Cribraria (Cribraria) cribraria cribraria*

#### CHINEN

*Mauritia (Arabica) arabica asiatica*  
*Cypraea (Lyncina) vitellus vitellus*  
*Luria (Basilitrona) isabella rumphii*  
*Pustularia (Pustularia) cicercula cicercula*  
*Pustularia (Ipsa) childreni samurai*  
*Erosaria (Erosaria) erosa phagedaina*  
*Erosaria (Ravitronea) caputserpentis caputserpentis*  
*Staphylaea (Nuclearia) nucleus nucleus*  
*Erronea (Erronea) ovum ovum*

#### ONNA TIDE FLAT

*Cypraea (Lyncina) lynx vanelli*  
*Cypraea (Lyncina) vitellus vitellus*  
*Monetaria (Monetaria) moneta rhomboides*  
*Erosaria (Ravitronea) labrolineata labrolineata*  
*Erosaria (Ravitronea) helvola helvola*  
*Erosaria (Erosaria) erosa phagedaina*

*Staphylaea (Staphylaea) staphylaea staphylaea*  
*Staphylaea (Staphylaea) limacina limacina*  
*Erronea (Erronea) erronea erronea*  
*Erronea (Erronea) cylindrica cylindrica*  
*Notadusta punctata atomaria*  
*Palmadusta asellus vespacea*  
*Palmadusta clandestina moniliaris*  
*Purpuradusta gracilis japonica*  
*Purpuradusta fimbriata marmorata*  
*Bistolida (Blasicrura) luchuana*  
*Bistolida (Derstolida) hirundo neglecta*  
*Cribraria (Cribraria) cribraria orientalis*

## METASAKI REEF FLAT

*Talparia talpa talpa*  
*Cypraea (Lyncina) argus argus*  
*Cypraea (Lyncina) lynx vanelli*  
*Cypraea (Lyncina) carneola carneola*  
*Luria (Basilitrone) isabella rumphii*  
*Erosaria (Erosaria) poraria scarabaeus*  
*Staphylaea (Nuclearia) nucleus nucleus*  
*Palmadusta asellus vespacea*

## MINAMI-UKIBARU

*Erronea (Melicerona) felina pauciguttata*  
*Purpuradusta gracilis japonica*  
*Bistolida (Derstolida) kieneri depriesteri*

## MACHINATO REEF

*Mauritia (Arabica) arabica asiatica*  
*Cypraea (Lyncina) carneola carneola*  
*Erosaria (Ravitrone) caputserpentis caputserpentis*  
*Erosaria (Erosaria) erosa phagedaina*  
*Staphylaea (Staphylaea) staphylaea staphylaea*  
*Erronea (Erronea) erronea erronea*

## OTABARU REEF

*Mauritia (Arabica) eglantina couturieri*  
*Erosaria (Ravitrone) caputserpentis caputserpentis*  
*Staphylaea (Staphylaea) limacina limacina*  
*Palmadusta clandestina moniliaris*  
*Cribraria (Cribraria) cribraria orientalis*

## GUSHICHAN

*Talparia talpa talpa*  
*Luria (Basilitrone) isabella rumphii*

*Pustularia (Pustularia) cicercula cicercula*  
*Staphylaea (Staphylaea) staphylaea staphylaea*  
*Staphylaea (Nuclearia) nucleus nucleus*

## MIYAKO REEF

*Mauritia (Leporicypraea) mappa mappa*  
*Mauritia (Arabica) eglantina couturieri*  
*Cypraea (Cypraea) tigris pardalis*  
*Erronea (Erronea) cylindrica cylindrica*

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<i>calxequina</i> .....	20, 25	<i>labrolineata</i> .....	17, 21, 31	<i>reticulata</i> <sup>s</sup> .....	24
<i>caputserpentis</i> .....	17, 18, 21, 32, 38, 39	<i>langfordi</i> .....	13	<i>rhinoceros</i> .....	22
<i>carneola</i> .....	17, 18, 20, 27, 38	<i>limacina</i> .....	18, 21, 33	<i>rhomboides</i> .....	17, 21, 30, 39
<i>caurica</i> .....	17, 22, 35	<i>listeri</i> <sup>s</sup> .....	22	<i>rumphii</i> .....	17, 18, 20, 28
<i>cernica</i> .....	17, 21, 31	<i>luchuana</i> .....	16, 18, 22, 39	<i>samurai</i> .....	17, 21, 30
<i>childreni</i> .....	17, 21, 30	<i>lurida</i> .....	20	<i>scarabaeus</i> .....	17, 18, 21, 32, 37
<i>chinensis</i> .....	16, 17, 23, 40	<i>lutea</i> .....	22, 37	<i>schilderorum</i> .....	20, 27, 28
<i>cicercula</i> .....	13, 17, 18, 20, 28, 29	<i>lynx</i> .....	17, 18, 20, 26, 38	<i>scurra</i> .....	17, 20, 24, 38
<i>cincta</i> <sup>s</sup> .....	31	<i>maculifera</i> .....	17, 20, 38	<i>staphylaea</i> .....	18, 21, 33
<i>clandestina</i> .....	17, 18, 22, 37	<i>mappa</i> .....	17, 18, 19, 23	<i>stolida</i> .....	17, 22, 40
<i>couturieri</i> .....	18, 23, 24	<i>mariae</i> .....	20, 28	<i>sulcidentata</i> .....	28
<i>cribraria</i> .....	17, 18, 23, 37, 41	<i>marmorata</i> .....	17, 18, 22, 38	<i>tabescens</i> <sup>s</sup> .....	39
<i>cruenta</i> <sup>s</sup> .....	40	<i>maturata</i> <sup>s</sup> .....	31	<i>talpa</i> .....	17, 18, 20, 25
<i>cylindrica</i> .....	18, 22, 35	<i>mauritiana</i> .....	19, 20, 25	<i>teramachii</i> .....	13
<i>dayritiana</i> .....	39	<i>mediocris</i> .....	13, 20, 29	<i>teres</i> .....	17, 22, 37, 39
<i>depressa</i> .....	24	<i>michaelis</i> <sup>s</sup> .....	26	<i>testudinaria</i> .....	20, 28
<i>depriesteri</i> .....	13, 18, 22, 39	<i>mikado</i> <sup>s</sup> .....	32	<i>tetsuakii</i> .....	13
<i>eglantina</i> .....	18, 23, 24	<i>miliaris</i> .....	17, 21	<i>tigris</i> .....	18, 20, 25, 26
<i>erosa</i> .....	17, 18, 21, 32, 38	<i>moneta</i> .....	17, 21, 30, 39	<i>tomlini</i> .....	31
<i>errones</i> .....	17, 18, 21, 22, 34, 35	<i>moniliaris</i> .....	17, 18, 22, 37	<i>ursellus</i> .....	13
<i>felina</i> .....	17, 18, 22, 40	<i>musumea</i> .....	22, 36	<i>vanelli</i> .....	17, 18, 20, 26, 38
<i>fimbriata</i> .....	17, 18, 22, 38	<i>nahaensis</i> .....	26	<i>vespacea</i> .....	18, 22, 37
<i>flaveola</i> <sup>s</sup> .....	31	<i>neglecta</i> .....	13, 18, 22, 37, 40	<i>victoriana</i> .....	22
<i>globulus</i> .....	13, 20, 29	<i>nucleus</i> .....	17, 18, 21, 34, 38	<i>vitellus</i> .....	17, 20, 26, 38
<i>gracilis</i> .....	17, 18, 22, 38, 40	<i>ogasawarensis</i> .....	17, 21, 31	<i>ziczac</i> .....	22, 38

<sup>s</sup> = synonym; <sup>n</sup> = nomen nudum

## Systematic List of the Ryukyu Cowries

## CYPRAEIDAE FLEMING, 1828

Hist. Brit. Anim., 330 (em.) (Edinburgh)

## CYPRAEINAE STOLICZKA, 1867

Pal. Ind. (5), 2: 45

## Cypraeini SCHILDER, 1927

Arch. Naturgesch. 91/A: 92

*Mauritia* TROSCHER, 1863

Das Gebiß der Schnecken 1: 205

> Type Species: *Cypraea mauritiana* LINNAEUS, 1758 <(*Leporicypraea*) IREDALE, 1930

Mem. Queensld. Mus. 10 (1): 83

> Type species: *Cypraea mappa* LINNAEUS, 1758 <1. *Mauritia* (*Leporicypraea*) *mappa mappa*  
(LINNAEUS, 1758)

Systema Naturae, ed. 10: 718

(Arabica) JOUSSEAUME, 1884

Naturaliste 1884: 414

> Type species: *Cypraea arabica* LINNAEUS, 1758 <2. *Mauritia* (Arabica) *eglantina couturieri*  
(VAYSSIÈRE, 1905)

Journ. Conchyl. 53: 13; pl. 1, fig. 3

3. *Mauritia* (Arabica) *arabica asiatica*  
SCHILDER & SCHILDER, 1939

Proc. Malacol. Soc. London 18 (4): 183

4. *Mauritia (Arabica) maculifera* SCHILDER, 1932  
Zool. Anz. 100 (7/8): 165
5. *Mauritia (Arabica) scurra indica* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3412  
(*Mauritia*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea mauritiana* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 721
6. *Mauritia (Mauritia) mauritiana calxequina*  
(MELVILL & STANDEN, 1899)  
Journ. Conchol. 9: 236  
*Talparia* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 204  
> Type Species: *Cypraea talpa* LINNAEUS, 1758 <  
(*Talparia*) TROSCHER, 1863
7. *Talparia (Talparia) talpa talpa* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 720  
*Cypraea* LINNAEUS, 1758  
Systema Naturae, ed. 10: 718  
(em.) MONTFORT, P. DENYS DE, 1810  
Conchyl. Syst. 2: 630  
(*Cypraea*) LINNAEUS, 1758  
> Type Species: *Cypraea tigris* LINNAEUS, 1758 <
8. *Cypraea (Cypraea) tigris pardalis* SHAW, 1795  
Vivar. Natur. Misc. 6: plt. 193  
(*Lyncina*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea lynx* LINNAEUS, 1758 <
9. *Cypraea (Lyncina) argus argus* LINNAEUS, 1758  
Systema Naturae, ed. 10: 719
10. *Cypraea (Lyncina) lynx vanelli* LINNAEUS, 1758  
Systema Naturae, ed. 10: 721
11. *Cypraea (Lyncina) vitellus vitellus* LINNAEUS, 1758  
Systema Naturae, ed. 10: 721
12. *Cypraea (Lyncina) schilderorum* IREDALE, 1939  
Austral. Zool. 9 (3): 303
13. *Cypraea (Lyncina) carneola carneola* LINNAEUS, 1758  
Systema Naturae, ed. 10: 719
14. *Cypraea (Lyncina) kuroharai* (KURODA & HABE, 1961)  
Col. Illust. Shells of Japan 2: 42; plt. 19, fig. 17  
Luriini SCHILDER, 1932  
Fossil. Cat. 1: Animalia, pars 55, Cypraeacea
- Chelycypraea* SCHILDER, 1927  
(*Chelycypraea*) SCHILDER, 1927  
Arch. Naturgesch. 91A (10): 92  
> Type Species: *Cypraea testudinaria* LINNAEUS, 1758 <
15. *Chelycypraea (Chelycypraea) testudinaria testudinaria*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 719  
*Luria* JOUSSEAUME, 1884  
Bull. Soc. Zool. France 9: 92  
(Naturaliste 1884: 414, *nom. nud.*)  
> Type Species: *Cypraea lurida* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 720  
(*Basilitronea*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 93  
> Type Species: *Cypraea isabella* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 722
16. *Luria (Basilitronea) isabella rumphii*  
SCHILDER & SCHILDER, 1938  
Proc. Malacol. Soc. London 23 (3): 177  
Nariini SCHILDER, 1932  
Fossil. Cat. 1: Animalia, pars 55, Cypraeacea  
(Pustulariini SCHILDER, 1932)  
Fossil. Cat. 1: Animalia, pars 55, Cypraeacea  
*Pustularia* SWAINSON, 1840  
LARDNER's Encycl., p. 324  
(*Annepona*) IREDALE, 1935  
Austral. Zool. 8 (2): 114  
> Type Species: *Pustularia mariae* SCHILDER, 1927 <
17. *Pustularia (Annepona) mariae* (SCHILDER, 1927)  
Arch. Naturgesch. 91A (10): 104  
(*Pustularia*) SWAINSON, 1840  
LARDNER's Encycl., p. 324  
> Type Species: *Cypraea cicercula* LINNAEUS, 1758 <
18. *Pustularia (Pustularia) cicercula cicercula*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 725
19. *Pustularia (Pustularia) bistrinotata mediocris*  
SCHILDER & SCHILDER, 1938  
Proc. Malacol. Soc. London 23 (3): 126
20. *Pustularia (Pustularia) globulus globulus*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 725

- (*Ipsa*) JOUSSEAUME, 1884  
Naturaliste 1884: 415  
> Type Species: *Cypraea childreni* GRAY, 1825 <
21. *Pustularia (Ipsa) childreni samurai* SCHILDER, 1940  
Arch. Molluskenk. 72: 42  
(*Narinii* SCHILDER, 1932)  
Fossil. Cat. 1: Animalia, pars 55, Cypraeacea  
*Monetaria* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
(*Ornamentaria*) SCHILDER & SCHILDER, 1936  
Proc. Zool. Soc. London 1936: 1120  
> Type Species: *Cypraea annulus* LINNAEUS, 1758 <
22. *Monetaria (Ornamentaria) annulus annulus* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 723  
(*Monetaria*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea moneta* LINNAEUS, 1758 <
23. *Monetaria (Monetaria) moneta rhomboides* SCHILDER & SCHILDER, 1933  
Zool. Meded. Leiden 16: 163  
*Erosaria* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erosa* LINNAEUS, 1758 <  
(*Ravitronea*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 82  
> Type Species: *Cypraea caputserpentis* LINNAEUS, 1758 <
24. *Erosaria (Ravitronea) labrolineata labrolineata* (GASKOIN, 1849)  
Proc. Zool. Soc. London 1849: 97
25. *Erosaria (Ravitronea) cernica ogasawarensis* SCHILDER, 1944  
Arkiv Zool. 36 A (2): 23
26. *Erosaria (Ravitronea) helvola helvola* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 724
27. *Erosaria (Ravitronea) caputserpentis caputserpentis* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 720  
(*Erosaria*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erosa* LINNAEUS, 1758 <
28. *Erosaria (Erosaria) poraria scarabaeus* (BORY, 1827)  
Encycl. Méth. 3: 164; atlas (VALENCIENNES MS)
29. *Erosaria (Erosaria) erosa phagedaina* (MELVILL, 1888)  
Mem. Manchest. Lit. Soc. 4 (1): 223; fig. 11
30. *Erosaria (Erosaria) miliaris miliaris* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3420  
*Staphylaea* JOUSSEAUME, 1884  
Naturaliste 1884: 415  
(*Staphylaea*) JOUSSEAUME, 1884  
> Type Species: *Cypraea staphylaea* LINNAEUS, 1758 <
31. *Staphylaea (Staphylaea) staphylaea staphylaea*  
Systema Naturae, ed. 10: 725
32. *Staphylaea (Staphylaea) limacina limacina* (LAMARCK, 1810)  
Ann. Mus. Nat. Hist. Paris 15: 101  
(*Nuclearia*) JOUSSEAUME, 1884  
Bull. Soc. Zool. France 9: 98  
> Type Species: *Cypraea nucleus* LINNAEUS, 1758 <
33. *Staphylaea (Nuclearia) nucleus nucleus* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 724  
(*Erroneini* SCHILDER, 1927)  
Arch. Naturgesch. 91/A 10: 109  
*Erronea* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erronea* LINNAEUS, 1758 <  
(*Adusta*) JOUSSEAUME, 1884  
Naturaliste 1884: 414  
> Type Species: *Cypraea adusta* LAMARCK, 1810 <  
Ann. Mus. Hist. Nat. 16: 92  
= *Cypraea onyx* LINNAEUS, 1758
34. *Erronea (Adusta) onyx onyx* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 722  
(*Gratiadusta*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 82  
> Type Species: *Cypraea pyriformis* GRAY, 1824 <  
Zool. Journ. 1: 371
35. *Erronea (Gratiadusta) pulchella pulchella* (SWAINSON, 1823)  
TILLOCH's Phil. Mag. 61: 376

- (*Erronea*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erronea* LINNAEUS, 1758 <
36. *Erronea (Erronea) erronea erronea* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 723
37. *Erronea (Erronea) ovum ovum* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3412
38. *Erronea (Erronea) cylindrica cylindrica* (BORN, 1778)  
Index Mus. Caes. Vindob. 1: 169
39. *Erronea (Erronea) caurica caurica* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 723
- (*Melicerona*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 83  
> Type Species: *Cypraea listeri* GRAY, 1824 <  
Zool. Journ. 1: 384  
= *Cypraea felina* GMELIN, 1791  
Systema Naturae, ed. 13: 3412
40. *Erronea (Melicerona) felina pauciguttata*  
(SCHILDER & SCHILDER, 1938)  
Proc. Malacol. Soc. London 23 (3): 161  
*Notadusta* SCHILDER, 1935  
Proc. Malacol. Soc. London 21 (4): 350  
> Type Species: *Notadusta victoriana* SCHILDER, 1935 <  
Proc. Malacol. Soc. London 21 (4): 350
41. *Notadusta punctata atomaria* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3412
42. *Notadusta katsuae* (KURODA, 1960)  
Cat. Moll. Fauna Okinawa 1960: 74; plt. 3, figs. 32 - 34
43. *Notadusta musumea* (KURODA & HABE, 1961)  
Color Illust. Shells Japan 2: 42; plt. 19, fig. 18
- Palmadusta* IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 82  
> Type Species: *Cypraea clandestina* LINNAEUS, 1758 <
- (*Palmadusta*) IREDALE, 1930
44. *Palmadusta (Palmadusta) asellus vespacea*  
(MELVILL, 1905)  
Journ. Conchol. 11: 192
45. *Palmadusta (Palmadusta) clandestina moniliaris*  
(LAMARCK, 1810)  
Ann. Mus. Hist. Nat. Paris 16: 98
46. *Palmadusta (Palmadusta) lutea lutea* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3414
47. *Palmadusta (Palmadusta) ziczac ziczac*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 722
- (*Purpuradusta*) SCHILDER, 1939  
Arch. Molluskenk. 71: 165  
> Type Species: *Cypraea fimbriata* GMELIN, 1791 <  
Systema Naturae, ed. 13: 3420
48. *Palmadusta (Purpuradusta) gracilis japonica*  
(SCHILDER, 1931)  
Zool. Anz. 96: 67 - 68
49. *Palmadusta (Purpuradusta) fimbriata marmorata*  
(SCHRÖTER, 1804)  
Wiedem. Arch. Zool. 4 (1): 14
- Bistolida* COSSMANN, 1920  
Rev. Crit. Paléozool. 24: 83  
> Type Species: *Cypraea stolidia* LINNAEUS, 1758 <
- (*Blasicrura*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 84  
> Type Species: *Cypraea rhinoceros* SOUVERBIE, 1865 <  
Journ. Conchyl. 13: 156; plt. 511
50. *Bistolida (Blasicrura) quadrimaculata quadrimaculata*  
(GRAY, 1824)  
Zool. Journ. 1: 376
51. *Bistolida (Blasicrura) pallidula pallidula*  
(GASKOIN, 1849)  
Proc. Zool. Soc. London 1849: 97
52. *Bistolida (Blasicrura) luchuana* KURODA, 1960  
Catal. Moll. Fauna Okinawa 74; plt. 3, fig. 40
53. *Bistolida (Blasicrura) teres teres* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3405
- (*Bistolida*) COSSMANN, 1920  
Rev. Crit. Paléozool. 24: 83  
> Type Species: *Cypraea stolidia* LINNAEUS, 1758 <
54. *Bistolida (Bistolida) kieneri depriesteri*  
(SCHILDER, 1933)  
Journ. Conchol. 19: 355
55. *Bistolida (Bistolida) hirundo neglecta*  
(SOWERBY, 1837)  
Catal. Rec. Cypraeidae, London 1: 6
56. *Bistolida (Bistolida) stolidia stolidia* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 724

*Cribraria* JOUSSEAUME, 1884

Bull. Soc. Zool. France 9: 94

- > Type Species: *Cypraea cribraria* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723

## (Ovatipsa) IREDALE, 1931

Rec. Austral. Mus. 18 (4): 219

- > Type Species: *Cypraea chinensis* GMELIN, 1791 <

57. *Cribraria* (*Ovatipsa*) *chinensis chinensis*  
(GMELIN, 1791)

Systema Naturae, ed. 13: 3421

## (Cribraria) JOUSSEAUME, 1884

Bull. Soc. Zool. France 9: 94

- > Type Species: *Cypraea cribraria* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723

58. *Cribraria* (*Cribraria*) *cribraria orientalis*  
SCHILDER & SCHILDER, 1940

Arch. Molluskenk. 72 (2/3): 43

## DISCUSSION AND STATISTICAL NOTES

1. *Mauritia* (*Leporicypraea*) *mappa mappa*  
(LINNAEUS, 1758)

- CATE, 1966: plt. 34; figs. 7 a, 7b -

Localities: 41, 45, 48, 69, 79, 85

(6) <sup>2</sup>	r <sup>3</sup>	L	W	H	Lip	Col <sup>1</sup>
Largest shell:		88.2	58.0	48.3	42	35
Smallest shell:		70.3	44.0	37.5	34	34

At present, this species has to be considered rare in the Ryukyu Islands, particularly so in the littoral area of Okinawa. Reports of its being found at the southern islands of Miyako and Yaeyama are made occasionally; however, only 3 other shells are presently known to have been found at Okinawa (all at Zampa-Misaki), 2 of these

<sup>1</sup> Shell measurements (in millimeters):

L = length of shell; W = width of shell; H = height of shell; Lip = number of teeth on outer lip; Col = number of teeth on columella, excluding terminal ridge.

<sup>2</sup> The numbers in parentheses indicate the number of specimens examined in each case.<sup>3</sup> The abbreviations refer to the relative abundance of the species in the Ryukyus: vr = very rare; r = rare; u = uncommon; rc = relatively common; c = common.

being dead shells. Sometimes the local market has a specimen for sale, but these are thought to have been brought

from the Philippine Islands. The 2 specimens whose measurements are listed above were collected in 1952, one at Zampa-Misaki, the other at Yaeyama Island. The Ryukyu shells, like those from Japanese waters, can usually be easily distinguished from the Philippine shells by the pale coloring on the base of the shell; the Okinawa shells are mostly light beige, sometimes exhibiting a faint flush of very pale brown, only occasionally pale pink. The southern Philippine shells, in contrast, usually are some shade of pink or rose. It is interesting to note that the base of the Japanese shell approaches an almost off-white color in many instances.

The shell is large, of medium weight, often more humped; base has a hint of flatness, gently convex abapically toward higher margins; terminals produced, acutely and strongly formed; apex never completely covered; margins thickened, evenly calloused, becoming vaguely flanged adapically, conspicuously so on either side in front; aperture fairly wide, almost straight; teeth fine (for a shell of this size), numerous, and not too heavily formed; columella broad, finely ribbed adaxially; fossula wide, fairly deep, with an upraised central ridge within, ribbed with teeth overall; primary shell color is ivory brown; the dorsal covering is a curious pattern of fine chestnut-brown, wavering, longitudinal lines; a wide tributary mantle pattern covers a large portion of the central dorsal surface (the species name is derived from this unique pattern); large, brown, diffused spots recede to obscurity from the sides to the base; base and terminals pale pink-brown blush to off-white, teeth, columella, fossula, and interstices ivory; there may be a large dark brown blotch at the spire. It is interesting to note that this species emits an intense red fluorescence when exposed to short-wave ultra violet light.

2. *Mauritia* (*Arabica*) *eglantina couturieri*  
(VAYSSIÈRE, 1905)

- CATE, 1966: plt. 35; figs. 8 a, 8 b -

Localities: 55, 59, 85

(6)	u	L	W	H	Lip	Col
Largest shell:		58.8	32.6	26.9	39	33
Smallest shell:		56.3	31.3	25.2	33	31

This species is somewhat difficult to find at Okinawa. As far as I know the shell is presently found only at Otubaru and Zampa-Misaki reefs, living hidden in coral crevices.

The shell is long, narrow, cylindrically-ovate, base somewhat flattened; terminals produced; aperture long, narrow, wider in front; teeth numerous, fine, short; margins rounded, lightly calloused, right side sub-angled;

basic dorsal color greenish-grey, overlaid with an irregular network of chestnut-brown lines; there is a wide mantle line; numerous small (as compared with *Mauritia (Arabica) arabica asiatica*) dark brown spots thickly decorate sides; most spots are obscurely visible through thin callus; base and interstices smoky beige, teeth red brown.

3. *Mauritia (Arabica) arabica asiatica*  
SCHILDER & SCHILDER, 1939

— CATE, 1966: plt. 35: figs. 9 a, 9 b —

Localities: 3, 9, 13, 19, 20, 20 a, 33, 48, 51, 55, 57, 62 a, 65, 82, 85

(25)	c	L	W	H	Lip	Col
Largest shell:		67.2	40.2	31.3	32	28
Smallest shell:		38.0	22.2	17.0	31	25

This is one of the most common cowrie species occurring in the Ryukyu intertidal zone. It is usually found wedged within algae-covered coral crevices, in reef pools, and under rocks and rocky ledges. The frequency of this species in the adjacent outer islands is comparable to that at Okinawa. The shell varies a great deal in both size and shape, from short and wide to elongate and narrow, approaching the shell character of *Mauritia (Arabica) eglantina couturieri*. The large black spots on the heavy, calloused margins and the teeth on the columellar lip identify this species. Because of the similarity in general shape and color of the shells of this species to those of *M. (A.) arabica grayana* (SCHILDER, 1930) it has often been confused with this species (SCHILDER, 1966, p. 7). *Mauritia arabica asiatica* differs by having larger and fewer teeth, and by being more round, less pyriform; the elongate form of *M. arabica asiatica* poses no problem. The Erythraean shell is noticeably more abrupt, as well. The species seems to attain its largest dimensions at Yonabaru.

One form of this species is oblong-ovate, another stunted, short, broad, somewhat elevated, semi-cylindrical, swollen, and solid; base weakly convex, appearing flattened; apex prominent; terminals not produced, well formed; teeth numerous, fine on columella, larger, more widely spaced on outer lip; columella broad, channeled, ribbed; fossula long, broad, deeply concave, ribbed, denticles prominent on adaxial ridge; aperture straight, wide, more so and constricted in front; dorsal color covering dark, chestnut-brown, with longitudinal, closely parallel, broken brown lines and light-grey lacunae; a light-grey mantle line is also present; light-grey to beige margins are thickly covered with large, black spots; terminals grey-black to beige; base and interstices beige, teeth red-brown.

4. *Mauritia (Arabica) maculifera* SCHILDER, 1932

Syn.: [*Cypraea*] *reticulata* MARTYN, 1784 (non-binomial)

The Universal Conchologist 1: fig. 15. London

— CATE, 1965: plt. 8; figs. 26 a, 26 b —

Localities: 9, 29, 48, 85

(8)	u	L	W	H	Lip	Col
Largest shell:		59.8	37.9	29.6	27	25
Smallest shell:		41.5	28.3	20.9	24	20

The generic name for the synonym cited above has been placed in square brackets because MARTYN did not list a genus for this species; it became necessary to infer the name *Cypraea* from the preceding line in the text.

This species, in my experience, has the center of population in the Hawaiian Islands. Hawaii and Japan appear to be the northwestern limits of its living range. HABE (1961) listed and illustrated this species correctly; however he listed also *Arabica depressa* (GRAY, 1824), possibly in error (plt. 19, fig. 25). From the appearance of his illustration it would seem that his shell is a stunted form of this species. The range of GRAY's species apparently does not extend north of the Fiji Islands, it being a more southern, warmer water species, ranging to Cocos Keeling Island and elsewhere in the northeastern Indian Ocean.

The Ryukyu shells seem to be smaller on an average than the Polynesian form. The shell is comparatively small, solid, compact, oblong-ovate; margins heavily calloused, thick, bumpy; terminals short, restricted; aperture narrow, curving; columella broad, semi-denticulate; fossula long, wide, deep; base perceptibly swollen; teeth short, well defined on both lip and columella; primary shell color light beige, appearing as lacunae on dorsum; dorsum conspicuously red-brown, with a narrow mantle line on the right side; margins heavily speckled with large, black spots whose dilution in the nacre give the margins, terminals, and part of the base a dark blackish-grey cast; areas of the base, interstices, columella, and fossula light beige; teeth dark red-brown.

5. *Mauritia (Arabica) scurra indica* (GMELIN, 1791)

Syn.: *Cypraea amarata* MÖRCH, 1852

Cat. Conch. YOLDI, p. 114

— CATE, 1966: plt. 35; figs. 10 a, 10 b —

Localities: 19, 33, 85

(3)	u	L	W	H	Lip	Col
Largest shell:		44.5	23.2	18.9	39	35
Smallest shell:		38.3	20.1	15.8	43	32

This is not a common species, found only at three presently known locations, Zampa-Misaki, Kadena, and the dual island locality Henza-Miyagi. There seems to be no logical explanation for the greater number of teeth on the lip of the smaller shell listed above. The species is collected on algae covered dead coral outcroppings and under coral boulders.

The shell is cylindrically-oblong, solid, strong; terminals produced, heavily formed; aperture long, straight, narrow; teeth numerous, fine, somewhat longer on the central base; margins barely thickened, rounded; basic dorsal color is greyish-beige, overlaid with a network of yellow-brown lines, broken with numerous large lacunae; mantle line also present; margins, sides, base, interstices smoky-brown, teeth red-brown; large brown spots decorate the sides; terminal edges smudged with dark brown.

6. *Mauritia (Mauritia) mauritiana calxequina*  
(MELVILL & STANDEN, 1899)

— CATE, 1966: plt 34; figs. 5 a, 5 b —

Localities: 20, 23, 25, 27, 33, 45, 57, 63, 65, 85

(9)	u	L	W	H	Lip	Col
Largest shell:		97.4	68.5	50.3	28	21
Smallest shell:		82.5	58.7	42.3	27	20

This species probably seems uncommon because of its more or less isolated habitat. The animal is restricted to the outer surfaces of the reef and inaccessible headland promontories, living on the exposed rocky-slab surfaces facing the open ocean. At one locality on Miyako Island it was almost impossible to walk due to the number of these mollusks living on the substrate. It seems best suited to living in water 6 to 25 feet deep, in pounding, swirling surf, and even so it is difficult to find and collect. Yet at another island to the south, Iriomote, at a minus tide, 32 specimens were counted on a single reef-flat.

Shell medium sized, roundly-ovate, terminals inconspicuous, base and lip wide, concave overall; aperture somewhat narrow, curving left sharply adapically; margins sharply angled, solid; teeth strong, large, long; primary shell color very light beige-brown, appearing as lacunae in dark red-brown dorsal surface — sides solid, deep red-brown halfway up shell; base and teeth deep red-brown, interstices and terminals orange beige; mantle line sometimes present.

7. *Talparia (Talparia) talpa talpa* (LINNAEUS, 1758)

— CATE, 1966: plt. 35; figs. 11 a, 11 b —

Localities: 3, 9 a, 15, 35 b, 41, 63 a, 65, 85

(11)	u	L	W	H	Lip	Col
Largest shell:		82.5	44.4	36.1	53	47
Smallest shell:		46.5	25.2	20.8	41	36

Although this species has been found living at several localities around the island of Okinawa, it is not commonly encountered at any of them. MACNEIL (1960) reported: "fragments, internal molds, and otherwise poorly preserved specimens of Cypraeids were obtained from many localities." He suggests that *Talparia talpa talpa*, as indicated by the appearance of the shell fragments, may have been recovered from at least 8 localities in the Okinawan fossil beds. One recent collection of a living specimen was made at the edge of the reef off Gushichan; 2 or 3 beach specimens have also been recovered at Zampa-Misaki and Metasaki.

The shell is of medium size for the species, light weight, cylindrically elongate; base long, fairly narrow, vaguely convex; terminals produced, thickly, solidly formed; aperture long, narrow, nearly straight; margins thickened, more so on the right, gently angled; teeth numerous, fine, distinct, short; basic shell color ivory-yellow, with 4 wide transverse bands of light chestnut-brown; interstices lighter in color, nearly off-white; wide, partially ribbed columella yellow-brown; short, wide, deep, off-white fossula is ribbed and denticulate adaxially.

8. *Cypraea (Cypraea) tigris pardalis* SHAW, 1795

— CATE, 1966: plt. 34; figs. 6 a, 6 b —

Localities: 27, 33, 35 a, 48, 51, 57, 57 a, 59, 63 a, 65, 65 a, 81, 85

(5)	u	L	W	H	Lip	Col
Largest shell:		87.5	64.4	51.6	27	20
Smallest shell:		81.2	59.5	44.9	27	19

This species is not very plentiful, being found only now and then. It lives on coral shelves just below low tide mark. Fishermen most often, in diving operations, bring shells of this species in and offer them in the market place. The Naha limestone formation has yielded a fossil fragment, according to MACNEIL (1960), of a large *Cypraea* that seems related to *C. tigris pardalis*, but appears to differ from it by possessing a depressed area on the right lip just adjacent to the base of the teeth. From his excellent figure (*l. c.*, plt. 17, fig. 1) it is impossible to determine whether the depressed area is there because of a loss in shell material, or is the morphological character of a different species. The base on the left side appears to exhibit signs of surface attrition as well. It is conceivable that the sloughing away of the thick marginal callus on

either side and on the base could leave the shell's teeth elevated in a manner such as this figure illustrates. Fragmentary evidence of this marginal callus still clings to the right side of the MacNEIL shell. The visible apertural teeth seem to conform with those of the species as we know it today. The Ryukyu *C. tigris pardalis* that I have examined seem to be of smaller dimension than those seen from the more southern Philippine area. A recent discovery (Way) shows the species to be actually quite common half a mile off shore at Kin Bay, in 35 to 40 feet of water.

The shell is of medium size, medium weight, solid, subpyriform; base and lip swollen, concave to aperture; aperture wide, fairly straight; terminals barely protruding; margins rounded, thickened; columella unribbed adapically, ribbed abapically to and including the broad, shallow fossula; basic shell color on dorsum varies in shades of brownish-orange, overlaid with large, diffused black spots that continue over the sides and margins to the base; columella marked with vague orange-brown; base, teeth, and interstices are white.

9. *Cypraea (Lyncina) argus argus* LINNAEUS, 1758

— CATE, 1966: plt. 33; figs. 3 a, 3 b —

Localities: 1, 33, 35 a, 41, 85

(4)	u	L	W	H	Lip	Col
Largest shell:		80.5	43.5	35.6	40	37
Smallest shell:		61.3	30.8	24.4	35	38

The large shell, whose measurements are recorded here, was collected in early December, 1954, at Metasaki. Live-collected shells of this species are rare, although beach shells in good condition are found from time to time at this locality and at Zampa-Misaki. MACNEIL (1960) describes a related species from the Naha Pliocene lime formation, *Aristorides nahaensis*. He says, that although closely related to *Aristorides argus argus* (LINNAEUS, 1758), it differs most importantly in that the columellar teeth do not extend into the aperture, apparently not crossing the columella or fossula. Its length and width are given as 40 mm and 24 mm, respectively. The holotype is in the U. S. National Museum with the catalogue number 563023.

Shell of medium size, relatively light weight, cylindrically elongate, abruptly elevated front and back, central dorsal surface almost horizontal; base and lip convexly rounded; terminals inconspicuous; aperture wide, nearly straight; margins lightly calloused, more so, but narrowly restricted, on the right side, thickly enveloping the terminal openings; teeth numerous, short, well defined; columella broad, fossula long, becoming deeper in front, both strong-

ly ribbed with teeth; primary shell color creamy-cocoa, overlaid dorsally with 3 wide, transverse pale cocoa-colored bands, and over all, numerous "eyes" or ocellae; many are thin-lined rings, others, less numerous, are larger, thick-lined, heavier ocellae; 4 large, brown, ventral blotches at either quarter of the base — sometimes the right rear blotch is incomplete or missing; terminals, base, teeth, and interstices creamy-cocoa; teeth outlined on either side with a fine broken line.

10. *Cypraea (Lyncina) lynx vanelli* LINNAEUS, 1758

Syn: *Cypraea lynx* var. *michaelis* MELVILL, 1905

Journ. Conchol. 11: 192

— CATE, 1966: plt. 35; figs. 12 a, 12 b —

Localities: 17, 33, 37, 39 a, 41, 55, 57, 65, 85

(4)	u	L	W	H	Lip	Col
Largest shell:		41.6	24.7	21.8	27	21
Smallest shell:		30.7	17.8	15.1	22	18

This species is uncommonly found on the coral reefs, living on ledges, in cavernous tunnels, and in algae covered tide pools. The invasion of this species into these islands seems to be of relatively recent date, as there appears to be no reference to its being found in the lime formations as late as the Pleistocene. Although comparing very favorably morphologically with the shells found in the Philippines, the Ryukyu shells seem to be generally smaller in size and narrower, with a distinctly deeper dorsal coloring.

Shell narrowly ovate, solid; margins thickened, more so on the right side, somewhat angled; terminals semi-produced, well developed; aperture narrow, only slightly curving; columella broad, fossula shallow, both heavily denticulate; base flattened, sloping sharply adaxially, lip rounded; primary shell color light beige, overlaid dorsally with light yellow-brown, with large and small dark brown spots irregularly dotting the upper surface, becoming obscure in the marginal callus; teeth short, well defined, fine on columella, heavier on inner edge of outer lip; margins, base, and teeth light cream color, interstices bright orange.

11. *Cypraea (Lyncina) vitellus vitellus* LINNAEUS, 1758

— CATE, 1966: plt. 36; figs. 17 a, 17 b —

Localities: 1, 9, 13, 33, 37, 39, 57, 65, 81, 85

(7)	rc	L	W	H	Lip	Col
Largest shell:		38.9	26.3	21.1	23	18
Smallest shell:		31.5	19.8	17.0	21	19

This species is relatively common, occupying crevices and the underside of coral ledges. Most of the shells I have examined appear to be uniformly small for the species. The coloring is richly dark grey-brown, the smudge of which darkens the normally beige colored base. This species seems to be equally common at each of the localities listed.

Shell relatively small, abruptly humped, pyriformly-ovate, strong, solid; margins thickened, especially the right side; terminals prominent, thickly formed; base and lip swollen; aperture somewhat narrow, fairly straight; teeth do not extend onto base, are semi-fine, long, crossing the broad columella and the long, shallow fossula; teeth on lip somewhat longer, heavier, more numerous; dorsal color dark grey-brown, copiously marked with large and small spots; margins fawn, with the characteristic numerous, fine transverse striae, sweeping from the outer line of the base teeth to well up onto either side of the dorsum; teeth pale ivory, most of the base and interstices pinkish-fawn to light grey.

12. *Cypraea (Lyncina) schilderorum* IREDALE, 1939

Syn.: *Cypraea arenosa* GRAY, 1824

Zoolog. Journ. 1: 147; plt. 7, fig. 6; plt. 12, fig. 6

— CATE, 1965: plt. 9; figs. 31 a, 31 b —

Localities: 49, 51, 77

(2)	r	L	W	H	Lip	Col
Largest shell:		35.3	23.0	17.5	32	25
Smallest shell:		31.0	22.0	16.3	29	22

In the synonym cited above, DILLWYN (1823) invalidated this name by publishing SOLANDER's name *arenosa* (Index Lister Hist. Conch., p. 33, 1823) and no other names were available; a new name, therefore, became necessary.

This species is rare in the Ryukyu Islands. The smaller shell recorded above was collected in 1952 on the beach at Nago. Broken beach-worn shells have been collected at the same locality, and it is probable that SCUBA-diving will some day produce live-collected specimens. The larger shell, also a beach specimen, was found at Yabu. Both shells appear to be typical representatives of the species. MACNEIL (1960, p. 50) recorded a single, imperfect specimen from the Pliocene limestone at Naha. His figures (*l. c.*, plt. 17, figs. 4 - 8) are well defined and clearly seem to represent this species.

Shell ovate, perceptibly flattened, solid, heavy; terminals inconspicuous, especially adapically; aperture straight, narrow; margins thickly calloused, sharply angled; teeth short, fine, numerous; base generally convex; primary

shell color beige to off-white; dorsum dark beige, overlaid transversely with 4 somewhat narrow reddish-beige bands; marginal beige callus covers sides well up onto shell; conspicuous grainy texture and numerous vertical striae in the lateral callus; portion of base, teeth, and interstices off-white.

13. *Cypraea (Lyncina) carneola carneola* LINNAEUS, 1758

— CATE, 1966: plt. 36; figs. 16 a, 16 b —

Localities: 9, 39, 41, 65, 85

(5)	rc	L	W	H	Lip	Col
Largest shell:		33.0	21.7	18.2	27	21
Smallest shell:		25.0	14.7	12.1	27	22

This species is rather uncommon, although it has been collected at several localities. When it is found it is usually on coral ledges of the reef adjacent to deep water. At Zampa-Misaki it was found nestling in crevices around the circumference of a littoral area locally referred to as the Punchbowl. It was living under clusters of a certain species of sea anemone that nearly covered that portion of the reef floor. These shells, like so many other cowrie species in the Okinawa area, are comparatively smaller in size than those from Philippine waters. Nearly all of the specimens I have observed appear to have broken lips that subsequently have been mended in the process of continued growth.

Shell oblong-ovate, solid, small; margins heavily calloused, somewhat bumpy in fully adult shells; terminals inconspicuous, though strong and thickly formed; base semi-rounded, uneven; aperture fairly straight, curving left only slightly; teeth well developed, but not lengthened onto base or lip; columella broad, fossula long, deep, and prominently ribbed adapically by the inner teeth; primary shell color pale grey-blue, overlaid with 4 bands of pale tomato-red; margins have a grainy texture of deep beige, base and terminals somewhat lighter in color; teeth and interstices bright violet.

14. *Cypraea (Lyncina) kuroharai* (KURODA & HABE, 1961)

(Plate 3, Figures 2 a, 2 b)

Localities: 53, 62

(1)	vr	L	W	H	Lip	Col
Shell measurements:		41.2	27.6	22.4	28	27

This is an extremely rare species and is supposed to have been taken only in Ryukyu waters. Specimens that I know of are as follows: Akibumi Teramachi, Kyoto, a live-collected specimen and one from the Ryukyu Islands; in

another collection there is one allegedly from Kyushu (Koshik Islands), one from Kii and two from Tosa Bay. Kurohara has one specimen, Sugatani has one, and one live-collected one is in the author's collection (Cate no. C3214) (Plate 3, Figures 2a, 2b). SCHILDER (1963) mentions two specimens, one in the Habe collection ( $L = 42$  mm), and one (subfossil) in his own collection (Schilder no. 15820). The specimen whose measurements are listed here for comparative purposes was live-collected in 70 fathoms by trawling off Tosa, Japan, in 1962. It compares favorably with the holotype in mensurable characters. Although shells of this species have been in Japanese collections for many years, it was only recently recognized as being different from *Cypraea* (*Lyncina*) *arenosa* GRAY, 1824 (= *C. schilderorum* IREDALE) for which it had previously been mistaken; it had also been compared with *C. (L.) sulcidentata* GRAY, 1824, by some workers.

Shell pyriformly ovate, heavy, solid; margins thickened, though not prominently so; terminals prominent, openings narrow, thickly formed; base and outer lip swollen, rounded; aperture narrow, curving left apically; teeth short, not extending onto base or lip, very fine, sharp; those on columella larger, extending pointedly into aperture; columella fairly broad, fossula short and deep, both ribbed with columellar teeth; terminal ridge straight; primary shell color beige, base lighter beige, margins darker beige and grained; dorsum faintly marked with 4 broad, deep tan transverse color bands; lower terminal surface, base, teeth and interstices light creamy-beige.

15. *Chelycypraea (Chelycypraea) testudinaria testudinaria* (LINNAEUS, 1758)

— CATE, 1966: plt. 33; figs. 4a, 4b —

Localities: 45, 47, 62, 63

(7)	u	L	W	H	Lip	Col
Largest shell:		112.8	56.4	44.0	45	43
Smallest shell:		105.5	50.0	44.5	46	45

The shells used in this study were sent from Okinawa on various dates during 1952 and 1953 without specific locality data, the accompanying labels simply reading "Okinawa". This is regrettable; however, a report from Bernice Albert of Okinawa states: "... we have one we found with some tiger cowries the fishermen had brought in, but they are rather vague as to where they had found it. We have known of others brought in by fishermen, but none by divers or collectors." Further exploration will be needed in this area to ascertain the extent of the distribution of this species here.

Shell large, ponderous, solid, strong, cylindrically elongate; base somewhat swollen, yet because of its size

seems flattened; terminals prominent, apex a part of left side; aperture long, straight, wide; rear half of columella smooth, front half and the long, wide, deeply concave fossula ribbed with teeth; teeth on both lips comparatively small, weakly formed, very short; margins only barely calloused, rounded; primary shell color café-au-lait to beige, overlaid with large, irregular areas of brown, including many various sized large brown spots — additionally a thick haze of fine white specks is spread over all; base, inner terminals, and interstices of primary shell color, teeth light beige.

16. *Luria (Basilitrona) isabella rumphii* SCHILDER & SCHILDER, 1938

— CATE, 1966: plt. 35; figs. 13a, 13b —

Localities: 9, 13, 15, 33, 41, 57, 85

(5)	u	L	W	H	Lip	Col
Largest shell:		26.7	14.8	12.2	36	29
Smallest shell:		25.9	14.9	12.0	32	26

This is not a common species, though it is relatively well distributed throughout the island's waters. Adult shells are not very large and are fairly well characterized by a distinctly wide, flattened upper shell surface traversing the central dorsal area from side to side. This species grows comparatively larger in the Philippines and still larger in Hawaii.

Shell cylindrically ovate, narrow, solid; margins only barely thickened; terminals blunt, weakly formed; base area narrow, semi-flattened, lip rounded as is left marginal surface; aperture long, narrow, slightly angled abapically; teeth very short, extremely fine, though well developed, extending neither onto base nor lip; columella long, fossula deep, smooth, adaxial edge of fossula denticulate; primary shell color white, overlaid dorsally with fawn-grey; two narrow, lighter beige-colored bands divide the upper surface transversely, and numerous irregular, fine, black horizontal lines over all lengthwise; terminals orange, faintly quadrimaculate with dark brown; lower margins, base, teeth and interstices stark white.

17. *Pustularia (Annepona) mariae* (SCHILDER, 1927)

Syn.: *Cypraea annulata* GRAY, 1825 (nom. nud.)

Zool. Journ. 1: 518

*Cypraea annulata* GRAY, 1828

Zool. Journ. 4: 88

— CATE, 1966: plt. 36; figs. 18a, 18b —

Localities: 7, 49, 55

This species is rare in the Ryukyu Islands as it is at all other localities. Indications are that it lives in deep water as it is almost never found intertidally, only occa-

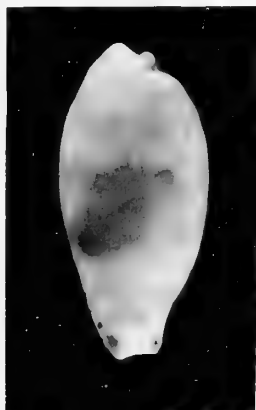


Figure 1 a



Figure 1 b

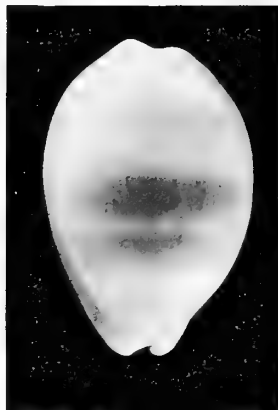


Figure 2 a



Figure 2 b



Figure 3 a

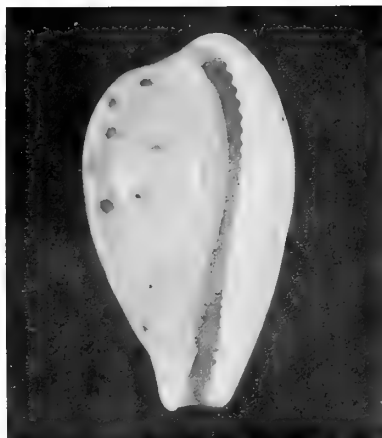


Figure 3 b

Figures 1 a, 1 b:

*Notadusta katsuae* (KURODA, 1960), ex C. N. Cate Coll. no. 3392; (x 2)

Figures 2 a, 2 b:

*Cypraea (Lyncina) kuroharai* (KURODA & HABE, 1961), ex C. N. Cate Coll. no. 3214;  
(natural size)

Figures 3 a, 3 b:

*Notadusta musumea* (KURODA & HABE, 1961), ex P. Clover Coll. (x 1½)



(2)	r	L	W	H	Lip	Col
Largest shell:		15.2	10.2	9.0	35	23
Smallest shell:		11.0	7.4	6.7	31	22

sionally as beach rolled shells. The two shells, whose measurements are recorded here, and a broken fragment of a shell were collected as dead beach specimens at Okinawa by Anita Scott in 1952. Recently another dead beach shell was found at Baten, a second shell was picked up on the beach just south of Nago. Nothing more can be reported on this species at this time.

Shell thin, lightweight, bulbously ovate; base narrow on either lip, peculiarly flattened; terminals barely visible; aperture long, exceedingly narrow, curving gently; teeth very fine, weak, poorly developed, almost obscure on inner lip; margins not thickened, a rounding continuation of the dorsum; primary shell color milk-white, upper surface and sides thickly covered with ocellated, irregularly shaped and sized straw-colored spots; base, teeth, and interstices milk-white.

18. *Pustularia (Pustularia) cicercula cicercula*  
(LINNAEUS, 1758)

— CATE, 1966: plt. 36; figs. 19 a, 19 b —

Localities: 13, 15, 43, 75

(10)	u	L	W	H	Lip	Col
Largest shell:		18.9	11.5	9.9	31	25
Smallest shell:		14.5	8.8	8.0	26	22

Gushichan has been a productive locality for this species. More recently, however, freshly dead shells have been found at Chinen and Toyohara. I have live-collected specimens from Minami-Ukibaru Island, northern Buckner Bay, collected in 1953. MACNEIL (1960, p. 50; plt. 19, figs. 1, 2) seems to have mistaken this species for *Pustularia g. globulus* (see discussion of this shell here under the title of that species). It would therefore follow that *P. c. cicercula* has not been found in the fossil deposits of Okinawa.

Shell pyriformly-ovate, numerous, completely, pustulate dorsally; grooved mantle line originates within small, deep umbilicus; terminals extended, beaked, delicately formed; aperture long, narrow, straight; margins not thickened; base semi-inflated, convexly arched longitudinally; teeth numerous, fine, distinct, extending to both margins inclusive of terminal beaks; shell uniformly lemon-beige, glossy though pustulate.

19. *Pustularia (Pustularia) bistrinotata mediocris*  
SCHILDER & SCHILDER, 1938

— CATE, 1966: plt. 37; figs. 20 a, 20 b —

Localities: 33, 49, 59

(19)	u	L	W	H	Lip	Col
Largest shell:		20.4	12.9	11.7	30	24
Smallest shell:		15.7	9.4	8.7	27	23

The largest shell whose measurements are recorded here was picked up on the beach at Kadena, and two others, including the small one recorded here, were collected on the beach about a mile south of Nago. Other beach-rolled shells have been found at the latter locality and at Otabaru. I know of no live-collected specimens in Okinawan collections. Further field work may disclose the habitat of these mollusks.

Shell semi-ovate, globularly humped, lightweight, and strong; terminals extended; beaked; mantle line originates in shallow, vague umbilicus; margins thickened, upswept, smooth; aperture long, narrow, straight; base flattened, convexly elevated at either end; central dorsal area smooth (pustules absent), glossy; sides and ends of dorsal area thickly covered with pustules; teeth numerous, fine, distinct, extending out to either margin; primary shell color pale yellow-beige, dorsum with a light brown blush, with pustule crests darker brown and a large brown spot centrally situated, as well as one at each end.

20. *Pustularia (Pustularia) globulus globulus*  
(LINNAEUS, 1758)

— CATE, 1966: plt. 37; figs. 21 a, 21 b —

Localities: 31, 47, 69, 83

(8)	r	L	W	H	Lip	Col
Largest shell:		20.6	13.2	11.5	38	25
Smallest shell:		18.5	11.2	10.0	34	23

This species is quite rare at Okinawa. Few specimens are to be found in local collections. The shells listed here (Cate coll. no. C3390) were collected in the beach drift at Ishiza by Anita Scott in 1953; the most recent collections were made by Bernice Albert at Onna tide flat in 1965.

MACNEIL (1960, p. 50; plt. 19, figs. 1, 2) records "*Pustularia cf. P. cicercula* (LINNÉ) s. l.," and illustrates the shell. It seems to me that the shell shown in the figures cited rather clearly represents the nominate species, *P. g. globulus*. He states, "It lacks dorsal granules, has no indi-

cation of sulcus, and the teeth tend to become weak or absent towards the central part of the aperture." The lack of dorsal granules would appear to eliminate *P. c. cicercula*, and the weakening or shortening of the columellar teeth rather emphatically indicate *P. g. globulus*. This weakening of the central columellar teeth can be easily observed in a series of these shells, never in *P. c. cicercula*, and it is visible in the specimen illustrated in CATE, 1966 (plt. 37; fig. 21 b). The columellar teeth of all other species in the genus *Pustularia* are long and strong, extending to the margins; this species appears to be the exception.

Shell pyriformly ovate, humped, bulbous; margins defined, though barely perceptibly thickened, and upswept on the right side; terminals protrude, beaked; aperture long, narrow, curving slightly to the rear; teeth fine, numerous centrally on columella somewhat shortened; the columella and the deep fossula half-ribbed, half-smooth adaxially; shell color yellow-beige, copiously spotted with medium sized brown spots; base and interstices yellow-beige; teeth darkened, some light brown; faint brown marks at either quarter on the base. (It should be stressed that these color descriptions are taken from dead, though fairly fresh beach shells and do not represent the natural color of live-collected shells.)

21. *Pustularia (Ipsa) childreni samurai* SCHILDER, 1940

— CATE, 1966: plt. 37; figs. 22 a, 22 b —

Localities: 3, 13, 49, 57, 82

(13)	u	L	W	H	Lip	Col
Largest shell:		21.4	13.7	10.6	35	25
Smallest shell:		16.3	10.6	8.5	37	24

This cowrie species throughout its Indo-Pacific range seems always to be difficult to collect alive. The animals from the Ryukyu Islands are no exception, as those in most of the local collections have been gathered dead on the beaches. Onna, Nago, and Chinen are the localities where the species is most commonly found.

Shell rectangularly inflated, abruptly terminated at either end, base flattened, peculiarly flanged at the side of either terminal; terminals barely projecting adapically, hardly more so in front; aperture narrow, nearly straight; right margin thickened, upswept; mantle line grooved, originating from small, shallow umbilicus; teeth numerous, fine, sharply defined, each denticle a continuous ridge from columellar tooth across base and over dorsum, terminating as a tooth on the outer lip; shell color a deep, rich, faintly brown honey-yellow, color darker only on small spot at center of umbilicus.

22. *Monetaria (Ornamentaria) annulus annulus* (LINNAEUS, 1758)

Syn.: *Monetaria harmandiana* ROCHEBRUNE, 1884

Bull. Soc. Malacol. France 1: 90; plt. 2, fig. 5

— CATE, 1966: plt. 37; figs. 23 a, 23 b —

Localities: 9, 13, 17, 19, 23, 25, 33, 37, 39, 41, 65, 81, 85

(15)	c	L	W	H	Lip	Col
Largest shell:		27.6	20.0	14.3	12	11
Smallest shell:		15.0	10.3	7.8	9	9

This is one of the most common cowrie species living in Ryukyu tidal waters. It can be found plentifully on nearly all tide flats and shallow reefs. Adult shells seem to have a wide range in size variation, yet shells of a particular locality being fairly uniform; at Metasaki, for example, they are noticeably large. Especially observable in these shells are the numerous very fine central white lines that traverse the median, smoky-grey dorsal section of the shell; although perceptible in the shells from other localities, it seems more evident here.

Shell rhomboid-ovate, flat, broad, solid; margins solidly thick, angled, perceptibly upswept; terminals blunt, a continuation of the margins; base swollen, lip less so, flattened; aperture straight, widening to the front; teeth large, strong, well defined, lengthening slightly onto base and lip; columella smooth, fossula weak or missing entirely; primary shell color creamy-beige, central dorsal section light grey, transversely marked with numerous fine white lines, an orange line encircles the central dorsal area; sides, margins, terminals, base, teeth, and interstices of primary shell color.

23. *Monetaria (Monetaria) moneta rhomboides* SCHILDER & SCHILDER 1933

— CATE, 1966: plt. 37; figs. 24 a, 24 b —

Localities: 1, 3, 7, 11, 13, 15, 20, 33, 37, 39, 39 a, 51, 62 a, 65, 73, 75, 75 a

(18)	c	L	W	H	Lip	Col
Largest shell:		25.9	20.0	12.8	13	13
Smallest shell:		15.0	9.0	7.0	11	10

This is a common species at Okinawa, but not as plentiful as *Monetaria annulus annulus*. Like the latter species, it can be found on most of the tide flats. The shell's shape indicates that this subspecies is well named. The shells appear to be nearly identical with those from the Philippine area.

Shell rhomboid, flattened, margins protruding prominently adapically; margins thick, narrow, sharply angled;

terminals and openings thickly formed; base and lip convexly swollen; aperture straight, broadening slightly abapically; teeth well defined, finer on the columellar edge than on the lip; columella smooth, fossula weak or absent; primary shell color off-white to light ivory, central dorsal area yellow-green, with two distinct darker green narrow bands traversing dorsum from side to side; sides, terminals light ivory, becoming lighter in color on inner half of base, teeth, and interstices.

24. *Erosaria (Ravitrone) labrolineata labrolineata*  
(GASKOIN, 1849)

Syn.: *Cypraea flaveola* GRAY, 1825

Zool. Journ. 1: 502

— CATE, 1966: plt. 38; figs. 27 a, 27 b —

Localities: 19, 20, 41, 57, 61, 65, 82, 85

(7)	u	L	W	H	Lip	Col
Largest shell:		20.3	10.6	8.8	20	20
Smallest shell:		14.4	8.8	6.8	15	13

This uncommon species is occasionally found on the tide flats at low tide. The shells seem to have quite a wide size range in adults. MACNEIL (1960, p. 52; plt. 2, figs. 17, 18, 25) lists a species "*Cribraria (Talostolida)* aff. *C. (T.) cincta* (MARTIN, 1899)," from the Miocene clay of Yonabaru, Okinawa. The shell compares favorably morphologically with *Erosaria (Ravitrone) l. labrolineata*, and may indeed be this species.

A dead shell, without animal, was found in 110 feet of water at Metasaki.

Shell pyriform to oblong-ovate, sometimes cylindrical, base swollen; terminals prominent; margins thickened, mostly on the crenulated right side, angled, shouldered; aperture wide, more so abapically; teeth prominent, medium sized, shorter in the central columella area, larger, evenly dispersed on outer lip; columella smooth, fossula absent; primary shell color white, overlaid dorsally with greyish-white to dark grey (as seen in the mantle line), upon which is a covering of tawny, light-brown, broken with numerous large and very small light-grey lacunae; margins, more particularly the terminal collars, spotted and marked with chestnut-brown; terminals, base, teeth, and interstices white.

25. *Erosaria (Ravitrone) cernica ogasawarensis*  
SCHILDER, 1944

Syn.: *Erosaria tomlini maturata* KIRA, 1954

Japan. Shells Col. 1954: 39; plt. 19, fig. 11

— CATE, 1960: plt. 1; figs. 5, 5 a —

Localities: 20 a, 35, 85

(3)	r	L	W	H	Lip	Col
Largest shell:		31.9	20.7	16.7	22	17
Smallest shell:		27.6	17.7	13.7	21	16

This species, whose type locality is given as the Ogasawara Islands, is found in both Japanese and Ryukyu waters and may be said to belong equally to these two areas because of the proximity of the type locality to each. Even so, it is rare at Okinawa, only one specimen having been found there. This specimen was collected on the Zampa-Misaki reef flat on April 7, 1966 by Bernice Albert. This particular specimen, the fourth I have examined (23.2 15.3 12.0 19 15), appears to have just attained maturity as the shell is comparatively thin and lightweight.

Shell ovately pyriform, solid; terminals faintly produced; aperture wide, gently curving; teeth well defined, strong; right margin thickly calloused, upswept, angled, shouldered, pitted, left side barely thickened; primary shell color off-white, dorsum covered with light brownish-yellow and numerous faint off-white spots, a vague mantle line also present; both sides thickly covered with brown spots; terminals, base, teeth, and interstices off-white; narrow columella smooth, shallow fossula ribbed.

26. *Erosaria (Ravitrone) helvola helvola*  
(LINNAEUS, 1758)

— CATE, 1966: plt. 38; figs. 30 a, 30 b —

Localities: 33, 35, 37, 39, 47, 51, 57, 61, 63 b, 65, 67, 85

(7)	u	L	W	H	Lip	Col
Largest shell:		22.1	15.5	11.0	18	13
Smallest shell:		21.6	13.7	10.4	20	14

Though not at all common, the species is widely distributed. It is usually collected in reef areas, in coral recesses and on protected ledges. The Ryukyu shells are of average size for the species. MACNEIL (1960, p. 51; plt. 17, figs. 2, 6) reports finding the species in the Pliocene layer of the Naha limestone.

Shell ovate, short, broad, strong, base swollen; terminals short, well formed; margins thickened on either side, upswept, shouldered, crenulated; aperture narrow, curving; teeth large, bold, heavily formed, extending up onto base and lip, longer toward the rear on base; columella narrow, smooth, fossula long, shallow, ribbed; shell color light caramel-brown, overlaid dorsally with deep, rich brown; a faint grey mantle line and numerous, various sized off-white spots are exposed; terminal collars, spire pale lavender; margins, base, teeth, and interstices rich light caramel-brown, base slightly darker.

27. *Erosaria (Ravitronea) caputserpentis caputserpentis*  
(LINNAEUS, 1758)

Syn.: *Ravitronea caputserpentis mikado* SCHILDER & SCHILDER, 1938

Proc. Malacol. Soc. London 13 (3): 135

— CATE, 1966: plt. 38; figs. 31 a, 31 b —

Localities: 1, 3, 9, 13, 20 a, 37, 39, 39 a, 51, 59, 81, 85

(30)	c	L	W	H	Lip	Col
Largest shell:		36.0	26.9	17.7	19	15
Smallest shell:		26.9	19.8	12.9	14	12

This species is plentiful, living on reef flats, seemingly always adjacent to deep water. One specimen had a red streak of color along one side of the shell. In my experience the species appears to be most commonly found at Smuggler's Cove. In a study of series, involving at least 25 specimens each from three localities (Japan, Philippines, and Ryukyus), I was unable to detect any morphological or color differences. From my observations that this species has a more or less continuous distribution from the Sulu Sea and Tosa Bay, I have come to the conclusion that *Ravitronea caputserpentis mikado* SCHILDER & SCHILDER, 1938 must be considered a synonym of the nominate species. MACNEIL (1960, p. 51; plt. 17, figs. 2, 6) records shells of this species from the Naha layer of Pliocene limestone.

Shell rhomboidally-ovate, strong, heavy, wide, appearing flattened; margins well developed, sharply angled, curving, perceptibly upswept; terminals obscure, though well formed within; base and lip somewhat convex; aperture long, narrow, curving abruptly adapically; teeth large, of equal size on each lip, pointedly so on the apertural edge; sides and outer surface of base dark brown, remainder of base and interstices pastel shades of light brown and beige; central dorsal area light brown broken with numerous off-white spots of various sizes; a thin mantle line may be present.

28. *Erosaria (Erosaria) poraria scarabaeus* (BORY, 1827)

— CATE, 1966: plt. 39; figs. 32 a, 32 b —

Localities: 9, 41, 57, 59, 61, 77, 83, 85

(8)	rc	L	W	H	Lip	Col
Largest shell:		20.2	13.6	10.5	19	17
Smallest shell:		16.0	11.0	8.3	17	16

While seldom collected alive, shells of this species are quite often seen in the beach drift, especially at Zampamisaki. MACNEIL (1960, p. 52; plt. 18, figs. 19, 22)

appears to have recorded this species under the name *Palmadusta asellus* ("Cypraea" sp. aff. "C." *asellus* LINNÉ), from the Yontan limestone of Okinawa (see species 43 below for a discussion of this identification).

Shell ovate, longer than wide, strong; base convexly swollen, lip curving; margins heavily calloused, upswept, sharply angled, shouldered, and crenulated on the right side; terminals inconspicuous; aperture narrow, nearly straight; teeth fine, well developed, short, barely extending onto base and lip; dorsal color medium brown, with numerous darker lacunae having off-white centers; terminals and base deep lavender, teeth and interstices pale lavender.

29. *Erosaria (Erosaria) erosa phagedaina*  
(MELVILL, 1888)

— CATE, 1966: plt. 39; figs. 33 a, 33 b —

Localities: 3, 9 a, 13, 19, 33, 37, 39, 48, 51, 57, 62 a, 63 b, 65, 69 a, 81, 82, 83, 85

(11)	c	L	W	H	Lip	Col
Largest shell:		34.6	19.4	15.0	21	18
Smallest shell:		25.0	14.7	11.1	18	13

This species is quite common at several localities. It is found in coral pockets, under rocks, and under overhanging submerged ledges. It has been established in these islands for many centuries; MACNEIL (1960, p. 51; plt. 19, figs. 9, 12) records this species from the Pliocene (Naha limestone) and Pleistocene (Yontan limestone), Okinawa. The adult shells vary in size, though only occasionally becoming as large as the Philippine specimens, Yonabaru seeming to produce the exceptions.

Shell oblong-ovate, semi-umbilicate, solid, base convexly swollen; terminals produced, thickly formed; margins thickened, shouldered, and pitted on the right side, pitting extending over and around terminal collars; teeth coarse, well formed on outer lip, finer and shorter on the columella, receding to mere pustules centrally; aperture wide, straight, somewhat constricted adapically; basic shell color ivory with tannish-grey-green covering the dorsum; numerous off-white spots of various sizes, some encircled by a darker ring, speckle the upper surface, a faint mantle line is also present; base, teeth, and interstices ivory; both margins have the large brown marginal banding characteristic of this species; lateral divisions of margin pitting crested with a short, fine brown line.



30. *Erosaria (Erosaria) miliaris miliaris* (GMELIN, 1791)Syn.: *Cypraea inocellata* GRAY, 1828

Zool. Journ. 1: 504

- CATE, 1966: plt. 39; figs. 34 a, 34 b -

Localities: 57, 81, 85

(5)	r	L	W	H	Lip	Col
Largest shell:		41.6	24.8	19.4	18	12
Smallest shell:		31.2	20.0	15.5	16	14

The largest shell, whose measurements are recorded here, was collected alive by Anita Scott in 1957. It is completely adult and heavily calloused. The locality is cited simply as "Okinawa". Since then the species is known to have been found in at least three localities, most recently by Ernest Albert at Yagaji, Okinawa. His comments were: "Yagaji is sandy, with some areas supporting sea grass, while at the end of one edge of the locality it is gravelly and rocky. Although the sand flat is, for the most part, barren of rock I found this shell living under one near the gravel area. It seems to be of a deeper color than those we have seen from the Philippines, and the base is more pinkish. We searched for more but could find none."

Shell large, heavy, thickly calloused, pyriformly ovate; terminals prominent, fully developed; aperture fairly straight, wide, especially so abapically; margins heavily calloused, upswept, angled, crenulated along both sides and over terminal collars; teeth large, strong, short; dorsal color pale grey-green, lightened in shade by a thin white film of nacreous callus over all; terminals, base, teeth, and interstices white.

31. *Staphylaea (Staphylaea) staphylaea staphylaea* (LINNAEUS, 1758)

- CATE, 1966: plt. 39; figs. 35 a, 35 b -

Localities: 15, 39, 44, 57, 62 a, 75 b, 81

(5)	u	L	W	H	Lip	Col
Largest shell:		17.8	10.2	8.1	20	16
Smallest shell:		17.6	10.2	8.2	19	17

This species is not at all common. At Onna, on the east (China Sea) side of Okinawa, the two specimens whose measurements are recorded here, were found on a sand flat under a bush-like, green, spongy algal growth, whose base was embedded in a viscous black substance. The habitat of this species seems to be restricted to this type of alga in the Ryukyus. The shell seems to be typical in appearance for the species, but generally not as large as the Philippine specimens.

Shell comparatively small, oblong-ovate, solid, base somewhat flattened; terminals conspicuous, sharply formed; aperture straight, widening abapically; margins apparent, though scarcely projecting; teeth fine, prominent, extending across base and lip to margins; a fine, white lateral surface at the margins separates the dorsum from the base, dorsum pale grey-brown, with numerous fine, light grey-white pustules; a grooved, lateral mantle line bisects the right dorsum; terminals and teeth bright burnt-orange; base and interstices off-white; columella narrow, semi-concave; fossula long, narrow, more deeply concave; columella and fossula ribbed adaxially with a continuation of the base teeth.

32. *Staphylaea (Staphylaea) limacina limacina* (LAMARCK, 1810)

- CATE, 1966: plt. 39; figs. 36 a, 36 b -

Localities: 33, 44, 48, 52, 57, 59, 62 a, 75 b, 85

(7)	u	L	W	H	Lip	Col
Largest shell:		26.6	15.0	12.0	20	21
Smallest shell:		20.8	11.4	9.2	17	15

This species, like the preceding one, is not very common here. The larger shell, whose measurements are recorded here was collected at Off Island. This is a large rock pile, with accompanying reef, located on the outer periphery of Buckner Bay on the Philippine Sea side of Okinawa. The specimen was found on a +0.5 foot daytime tide, with its purple-black mantle and the animal fully extended. The smaller shell was collected from under a rock at the Onna tide flat at night on a +0.6 foot tide. Both shells are typical examples of *Staphylaea l. limacina*, though of smaller size than the comparable Philippines shells. An interesting observation regarding this species that may clarify past confusion as to its identification is that the shell seems to attain maturity through at least three separate, distinct stages of development. The first stage has a solid, smooth, dark brown shell; the middle stage has numerous white spots on the smooth brown dorsum; in the final stage, in completely adult shells, the smooth white spots become white raised pustules, and a grooved mantle line is added.

Shell elongately ovate, somewhat light in weight, base convex; margins distinct, though not overly thickened; terminals sharply produced; apex depressed; aperture long, narrow, more or less straight; teeth distinct, finely formed, short, not extending to margins, sometimes even shorter centrally on the base; dorsal color battleship grey, marked overall with numerous white spots which may or may not be pustulated; a grooved mantle line usually present; margins, base and lip are white; terminals deep

burnt-orange, teeth and interstices pale orange, each denticle peculiarly, characteristically outlined on either side with dark burnt-orange lines; columella and shallow fossula ribbed by extension of base teeth.

33. *Staphylaea (Nuclearia) nucleus nucleus*  
(LINNAEUS, 1758)

— CATE, 1966: plt. 39; figs. 37 a, 37 b —

Localities: 13, 15, 41, 47, 83, 85

(10)	u	L	W	H	Lip	Col
Largest shell:		20.4	12.4	10.1	25	17
Smallest shell:		17.5	10.8	9.2	25	18

An uncommon species in the Ryukyu Islands, it has been collected at Zampa-Misaki and Metasaki. Beach drift shells have also been found at Gushichan and Chinen. MACNEIL (1960, p. 51; plt. 19, figs. 5, 6) reports finding a fossil shell of this species in the Pleistocene limestone of Yontan.

Shell of medium size, ovate, granular-pustulate, strong; terminals produced, semi-beaked; aperture narrow, curving; base and margins thickened, the latter upswept; teeth fine, long, sharply defined, numerous, extending from aperture edge to either margin and up onto sides; grooved mantle line originates from a small, weak umbilical depression adapically; shell color uniform, except that dorsum reflects a light grey; granular surface, terminals, margins, base, teeth, and interstices medium beige.

34. *Erronea (Adusta) onyx onyx* (LINNAEUS, 1758)

— CATE, 1966: plt. 40; figs. 38 a, 38 b —

Localities: 19, 69, 75 b

(2)	r	L	W	H	Lip	Col
Largest shell:		36.0	21.3	17.8	20	18
Smallest shell:		32.6	19.6	15.9	19	17

This species, although occasionally found on tide flats, must be considered rare in the Ryukyu Islands at present. The two specimens listed here were found at Taguchi; another shell has been reported from Henza-Miyagi. Of this latter shell Bernice Albert says: "I found the only one of these that I know of having been found at Okinawa. It was stranded on a sandy tide flat here at Henza-Miyagi. I had the feeling it did not come from the sandy area and decided to investigate further, but the water toward the reef [was] so full of long-spined urchins and the water was so shallow to swim in we had to give up trying. We've looked in this area since and have never seen another. The animal was jet black and the animal sort of bubbly."

Shell medium sized, pyriformly-ovate, somewhat light in weight; terminals prominent; aperture straight, wide; margins well calloused, angled; teeth short, finer on inner lip, extending weakly onto broad columella, fossula interrupting the teeth that cross it, labial teeth larger, well formed; base swollen; dorsal coloring a succession of various shades of light brown (the characteristic light grey-white not present) superimposed upon one another, exhibiting the effect of mantle action; narrow band of the sides, margins, terminals, base, and interstices dark brown, teeth red-brown; interior of shell off-white.

35. *Erronea (Gratiadusta) pulchella pulchella*  
(SWAINSON, 1823)

— CATE, 1966: plt. 40; figs. 40 a, 40 b —

Localities: 27, 39, 71

(1)	r	L	W	H	Lip	Col
Shell measurements:		41.3	23.0	20.0	31	27

During the last few years trawling operations by fishermen in the Taiwan-Ryukyu Islands area have confirmed the occurrence of this species in these waters. There have been reports of collections off Iriomote Island, though this has not been substantiated. The specimen reported here was trawled in 48 fathoms off the island of Miyako, southern Ryukyu Sakishima Group; this is, to my knowledge, the first authenticated shell of this species from the Ryukyu Islands.

Shell large for the species, pyriform, inflated adapically; terminals prominent, sharply formed, front almost beaked; aperture straight in front, curving sharply left to the rear; teeth fine, long on the base, short on outer lip; margins barely thickened, subangled on the right; basic dorsal color whitish-beige, with small, scattered flecks of light-brown; white margins numerous spotted with medium brown spots, base and interstices off-white, teeth red-brown (cracks and condition of shell indicate the specimen may have been dead when trawled from the ocean bottom).

36. *Erronea (Erronea) erronea erronea* (LINNAEUS, 1758)

— CATE, 1966: plt. 40; figs. 42 a, 42 b —

Localities: 1, 19, 33, 39, 48, 51, 57, 65, 69 a, 75 b, 81, 85

(14)	c	L	W	H	Lip	Col
Largest shell:		26.2	14.0	11.5	17	14
Smallest shell:		18.3	10.0	8.0	15	13

This species is common and widely distributed. It is almost never found out in the open, at least in the daytime, but is seen under rocks and in dark coral crevices.

Shell elongately ovate, sub-pyriform, strong, lightweight in structure; dark brown apex visible in shallow umbilicus, base convexly swollen; terminals somewhat prominent; margins thickened, right side particularly so; aperture wide, becoming wider in front; teeth weak on both lips, often nearly absent to the rear on the base; columella perceptibly denticulate in front, fossula absent; dorsum pale greenish-grey, tribanded, over which are numerous fine flecks of lighter brown, while usually a larger dark brown blotch adorns the central area; terminals, margins, base, teeth, and interstices light to dark ivory.

37. *Erronea (Erronea) ovum ovum* (GMELIN, 1791)

— CATE, 1966: plt. 40; figs. 43 a, 43 b —

Localities: 7, 82

(5)	u	L	W	H	Lip	Col
Largest shell:		25.0	14.8	12.2	17	15
Smallest shell:		23.6	14.0	11.6	18	16

The two shells listed here were collected at Baten, on the southern rim of Buckner Bay. This species has also been collected at Onna on the south (China Sea) side of Okinawa. An interesting feature of the Ryukyu shells is the very pale yellow coloring of the interstices; usually it is much darker and a more obvious identifying character. The shells of this species are more pyriform than those of *Erronea e. erronea*, lack the brown dorsal blotch, base and terminal coloring is darker, and the aperture is wider, but more constricted abapically.

Shell pyriform, somewhat bulbous; terminals prominent; aperture straight, wide, openly constricted in front; margins calloused, semi-angled on the right side; teeth short, fine on the inner lip, larger, heavier on outer lip; columella smooth, fossula almost flat, ribbed; dorsal surface covered evenly with small, irregular pale brown spots (flecks), undercoloring off-white, creating a greenish appearance; margins, terminals, base, and teeth light beige, interstices very pale yellow.

38. *Erronea (Erronea) cylindrica cylindrica* (BORN, 1778)

— CATE, 1966: plt. 41; figs. 46 a, 46 b —

Localities: 37, 45, 57, 75 b, 79, 85

(4)	u	L	W	H	Lip	Col
Largest shell:		27.3	12.1	10.0	17	22
Smallest shell:		22.6	11.0	8.8	16	20

Although these shells are found more commonly at the southern islands of Miyako and Yaeyama, they are also collected on the tide flats at Onna, Kue, and Zampa-

Misaki. The narrowness of these shells seems, more than usual, to emphasize their length.

Shell long, narrow, cylindrical, somewhat lightweight; terminals protrude awkwardly; aperture straight, wide, openly constricted in front; left margin barely thickened or not at all, and perceptibly flanged abapically; right side narrowly thickened and angled; umbilicate, with black apex therein; dorsal color grey, irregularly blotched with chestnut-brown on top; large brown spots at each terminal (quadrimate); umbilicus, terminals, margins, base, teeth, and interstices off-white; columellar teeth long, fine, weak, heavier in front, crossing fossula; labial teeth short, strong, widely separated.

39. *Erronea (Erronea) caurica caurica* (LINNAEUS, 1758)

— CATE, 1966: plt. 41; figs. 44 a, 44 b —

Localities: 39, 41, 57, 85

(2)	r	L	W	H	Lip	Col
Largest shell:		39.9	19.7	16.1	20	19
Smallest shell:		38.7	20.0	16.3	16	17

This species is very scarce here, only 3 specimens at present being known from Okinawa. Two of these were found at Zampa-Misaki, one by a SCUBA diver in deep water, the other at nearby Bolo Point; the third specimen was picked up on the Onna tide flat by Ernest and Bernice Albert.

Shell long, narrow, with rounded base; terminals prominent, apex depressed; aperture wide, generally straight; teeth strong, bold, though finer on rear half of base; margins well calloused, more so on right side, angled and shouldered; basic dorsal color greenish-ivory, with 3 wide transverse bands of light brown, overall thickly flecked with light brown; large brown spots line both sides; margins, terminals, base, and teeth light beige, interstices brownish-beige.

40. *Erronea (Melicerona) felina pauciguttata* (SCHILDER & SCHILDER, 1938)

— CATE, 1966: plt. 41; figs. 47 a, 47 b —

Localities: 9, 21, 33, 41, 43, 57, 81, 85

(4)	u	L	W	H	Lip	Col
Largest shell:		18.9	11.0	8.2	13	12
Smallest shell:		15.0	8.2	6.0	12	14

This species has been collected intertidally at several locations at Okinawa; the most notable of these are Zampa-Misaki, Onna, Metasaki, and Yagaji. It may be

found fairly frequently at the offshore islands of Ikishima (on the reef flats), and Minami-Ukibaru (intertidally).

Shell oblong-ovate, with a suggestion of flatness; terminals obscure; aperture straight, comparatively wide; right margin thickened, angled; base flatly concave; teeth short, weakly developed on the rear half of base, stronger in front, prominent on outer lip; fossula flat, ribbed; dorsal color grey-green, overlaid with 4 (3 prominent) broken transverse bands of darker color, with a yellow wedge of color just to the rear of the front terminal collar; large, dark brown spots at either side of terminals and in a line along the right margin, scattered along the left margin; base, lip, teeth, and interstices pale ivory.

41. *Notadusta punctata atomaria* (GMELIN, 1791)

— CATE, 1966: plt. 41; figs. 48 a, 48 b —

Localities: 39 a, 41, 57, 65, 85

(8)	u	L	W	H	Lip	Col
Largest shell:		18.6	11.1	8.9	20	21
Smallest shell:		14.6	8.4	6.8	19	18

To the best of my knowledge this is a rare mollusk in Ryukyu waters. The specimens measured were collected in 1950 on the reef just north of Onna on the west coast, and at Metasaki in 1952 by Anita Scott. Shells also are known to have been collected at Zampa-Misaki.

Shell generally fairly large, pyriformly-ovate, light in weight, umbilicate; terminals produced; aperture wide, curving; margins barely formed on the left, thickened, minutely shouldered, and angled on the right, semi-flanged in front; shell color off-white to ivory-beige, teeth and terminal openings slightly darker beige; dorsum and margins numerous speckled with medium dark brown spots.

42. *Notadusta katsuae* (KURODA, 1960)

(Plate 3, Figures 1 a, 1 b)

Localities: 53, 62

(2)	r	L	W	H	Lip	Col
Largest shell:		20.5	11.0	8.8	30	28
Smallest shell:		20.1	9.9	8.6	31	24

KURODA cites only "Okinawa" as the type locality of this relatively newly discovered species. The fact that it was trawled in 80 m (presumably by fishermen) precludes the fixing of an exact locality for it. Fernando Dayrit, Diliman, Rizal, Philippines reports that practically all of the fishing for Manila markets is done off the eastern coast of Palawan Island, a possible general locality for this specimen. SCHILDER (1963, p. 127) records the holotype

as in the Teramachi collection (Kyoto). The smaller shell, whose measurements are listed here (Cate coll. no. C3392) was taken from the stomach of a fish in a Manila fish market, thus the exact locality for this shell is also unknown. It is conceivable that a migrating fish transported this specimen to the Philippine area from Japanese waters. Dr. Schilder (*in litt.*) mentions the species as coming from the Sulu Sea also.

Shell narrow, elongately ovate, thin, lightweight though strong; base convexly rounded, swollen; terminals beaked delicately though strongly, sharply defined; aperture long, narrow; inner columella narrow, smooth; fossula almost without depression; teeth numerous, very fine, somewhat long on lip, very short on inner edge of base; margins perceptibly thickened, more so on outer lip where sub-angled, shouldered; slightly flanged at either side in front; primary shell color dark beige, tri-banded with a darker shade dorsally, terminal beaks lighter color, margins covered thickly with various sized chestnut-brown spots, narrow base and interstices ivory-beige, teeth ivory within, chestnut-brown on the ridges without.

It should be emphasized that my description was made from an *ex pisce* specimen, although one in excellent condition; there is none of the dorsal spotting as seen in *Notadusta musumea*.

43. *Notadusta musumea* (KURODA & HABE, 1961)

(Plate 3, Figures 3 a, 3 b)

Locality: uncertain in Ryukyu waters

(1)	r	L	W	H	Lip	Col
Shell measurements:		22.8	12.7	10.6	30	28

This is a rare species, occurring in Ryukyu and southern Japanese waters. The specimen whose measurements are recorded here was trawled in 50 fathoms off Kochi, Shikoku, Japan (in the Tosa Sea). The species has also been obtained by trawling off Amami-O-Shima, in 40 fathoms. However, I have been unable to get any further information about the Ryukyu shell. SCHILDER (1963) believes this species to be synonymous with *Notadusta katsuae* (KURODA, 1960), but it appears to me to be distinct. I am tentatively listing *N. musumea* with the Ryukyu fauna until further field work brings the information on the species here into better perspective.

Shell light-weight, strong, pyriform, shallowly umbilicate; base broad, convexly swollen; terminal in front semi-beaked, obscure at rear except that right extremity of lip is flared; aperture straight, wide; columella smooth adapically, increasingly ribbed toward the front; fossula long, narrow, shallow, ribbed, prominently denticulate

along either side; teeth numerous, very fine; though distinct, interstices are shallow; teeth larger on lip, finer and more indistinct on base; left margin rounded, scarcely calloused, thickened, broadly upswept on right side, weakly shouldered; primary shell color light ivory, with a faint, narrow band transversely bisecting the dorsum; margins thickly flecked with medium-brown spots, the left side more thickly so, the dorsum is more sparingly flecked, somewhat methodically with very small brown spots; a large chestnut-brown spot covers a portion of apex and umbilicus which latter is partially obscured with opaque nacre.

44. *Palmadusta (Palmadusta) asellus vespacea*

(MELVILL, 1905)

— CATE, 1966: plt. 42; figs. 50 a, 50 b —

Localities: 7 a, 9, 33, 41, 57, 85

(8)	u	L	W	H	Lip	Col
Largest shell:		17.4	10.1	8.0	20	15
Smallest shell:		13.7	8.1	6.2	19	14

This species is often found living on coral ledges and under rocks at Zampa-Misaki, Bolo Point, and Metasaki. The animals seem to migrate more or less seasonally; one or two may be found on a collecting trip, then it may be a long time before another is seen. MACNEIL (1960, p. 52; plt. 18, figs. 19, 22) lists and illustrates a shell from the Yontan limestone of Okinawa that may belong to this species, though to me it seems more probably to be *Erosaria poraria scarabaeus* (BORY, 1827) (see CATE, 1966, plt. 39, figs. 32 a, 32 b). The shape of the shell, the lack of teeth on the front half of the columella, and the presence of an exaggerated umbilical area all tend to eliminate *Palmadusta asellus vespacea* from consideration here.

Shell oblong-ovate, solid, strong, umbilicate; terminals somewhat produced; aperture fairly narrow, straight; margins thickened, heavily so on the right side, upswept, shouldered, angled; primary shell color white; three wide dark brown bands traverse the dorsum from right side to adaxial edge of columella, bands partially obscured by thin layer of white callus on left margin and base; umbilicus, terminals, margins, base, teeth, and interstices white.

45. *Palmadusta (Palmadusta) clandestina moniliaris*

(LAMARCK, 1810)

— CATE, 1966: plt. 42; figs. 51 a, 51 b —

Localities: 14, 23, 25, 33, 37, 57, 59, 62 a, 65, 85

(5)	u	L	W	H	Lip	Col
Largest shell:		15.7	9.3	7.4	17	17
Smallest shell:		13.2	7.8	6.6	17	16

This species is far from common. At Imbu it has been collected under rocks, at Onna out on the tide flats. It has also been obtained at Kue and Zampa-Misaki.

Shell narrowly ovate, small but strong; terminals prominent; aperture nearly straight, curving gently apically; margins thickened, semi-angled on the right side; teeth small, distinct, short on outer lip, longer on the base; primary shell color white, overlaid dorsally with light grey-beige, bisected by a narrow transverse band of off-white; a yellow-beige spot toward the front, overall fine straw-colored lines mark a zigzag pattern on upper surface; terminals, margins, base, teeth, and interstices white.

46. *Palmadusta (Palmadusta) lutea lutea* (GMELIN, 1791)

— CATE, 1966: plt. 42; figs. 54 a, 54 b —

Localities: 9, 53, 85

(1)	r	L	W	H	Lip	Col
Shell measurements:		13.5	8.0	6.2	16	14

As this paper was nearly completed, a personal communication from Peter W. Way, Okinawa, was received which lists a species hitherto unknown in Ryukyu waters. It states in part:

"*Cypraea lutea* (Gmelin) was found by myself yesterday morning about 3:30 AM on the outer reef at Zampa-Misaki (Bolo). To my knowledge another has not been found on Okinawa before, at least there are none in any of the collections that I have seen.

"I took it to the Alberts last night and we cleaned it together. I wanted them to verify my claim, as I was by myself at the time I found it. Naturally, we were all in 'seventh heaven' about finding this item.

"The tide for 27 January, 1967 was -0.5 ft. at 0154 hours. About 0430, I made one last quick sweep of the dry outer reef and saw the *lutea*; it looked as if it had just crawled out of a hole in the reef. When I came upon the animal it was high and dry and was still moving.

"The animal: the foot was a bright orange-red; it had minute black marks /// or lines on the dorsal side; the mantle was a dark red (not intense) and had numerous, simple papillae which gave it a fuzzy appearance; the tentacles were also the same color as the foot, with black eyes. (The mantle was not as brilliant a red as the foot.)

"Other shells found were *Cypraea hirundo neglecta*, *C. helvola*, *C. cribraria*, *C. arabica*, *C. teres*, *C. asellus*, *C.*

*nucleus*, *C. punctata*, *C. maculifera*, *C. fimbriata*, *C. poraria*, *C. isabella*, *C. caputserpentis*, *C. carneola*, *C. vitellus*, *C. vanelli* (*lynx*), *C. erosa*, *C. pallidula*, *Conus geographus* and *Conus distans*. Another fellow found two *Cyp-raea punctata* and one *C. scurra*."

47. *Palmadusta* (*Palmadusta*) *ziczac ziczac*  
(LINNAEUS, 1758)

— CATE, 1966: plt. 42; figs. 55 a, 55 b —

Localities: 57, 65, 85

(1)	r	L	W	H	Lip	Col
Shell measurements:	11.1	10.6	8.6	16	15	

Until about a year ago this species had been thought extinct in Ryukyu waters. Since then one specimen has been collected in shallow water on the reef just north of the village of Onna; another has been found in the same locality in deeper water by a SCUBA diver; still more recently a specimen was collected at Bolo Point.

Shell short, wide, pyriformly ovate, umbilicate, with a swollen base; terminals weakly produced; aperture wide, gently curving left adapically; margin thickened only on right side; teeth short, well defined, finer on the base; basic dorsal color light grey, overlaid with light olive-brown in a zigzag manner, thereby exposing the light grey primary color; base, teeth, and interstices burnt-orange; medium dark brown spots encircle the umbilical area, numerous on base, less on sides; terminal edges medium brown.

48. *Palmadusta* (*Purpuradusta*) *gracilis japonica*  
(SCHILDER, 1931)

— CATE, 1966: plt. 43; figs. 56 a, 56 b —

Localities: 19, 37, 43, 57, 75 b

(3)	u	L	W	H	Lip	Col
Largest shell:	18.0	10.6	8.6	16	13	
Smallest shell:	15.0	9.2	7.3	15	12	

This is another uncommon species living in the intertidal zones of Okinawa. It is most frequently collected on the tide flats at Kue, Onna, and Henza-Miyagi.

Shell pyriform, semi-bulbous; terminals strongly produced; aperture wide, straight; right margin heavily calloused, sub-angled; teeth short, fine; primary dorsal color light grey-white, overlaid with numerous thin flecks of light brown, a larger dorsal blotch frequently present as well; large brown spots line both margins, both terminal openings lined with purplish-brown; base, teeth, and interstices ivory.

49. *Palmadusta* (*Purpuradusta*) *fimbriata marmorata*  
(SCHRÖTER, 1804)

— CATE, 1966: plt. 43; figs. 58 a, 58 b —

Localities: 9, 19, 33, 37, 57, 65, 81, 85

(18)	c	L	W	H	Lip	Col
Largest shell:		13.1	7.2	5.9	17	16
Smallest shell:		11.1	6.1	5.0	18	16

This species is found commonly under rocks and in coral at Kue, Onna, Yagaji, and Bolo Point. The shells closely resemble the Philippine forms and may be a link in the range of the species, which terminates in the Japanese islands to the north.

Shell sub-pyriform, bluntly flattened adapically; terminals obscure to the rear, less so in front; aperture fairly wide; teeth very fine, weaker on base; right margin thickened, angled, sub-shouldered; primary dorsal color light grey, overlaid irregularly with pale brown, with a wide, darker brown transverse broken band; apex and terminals deep lavender; margins, base, teeth, and interstices off-white.

50. *Bistolida* (*Blasicrura*) *quadrifasciata quadrifasciata*  
(GRAY, 1824)

— CATE, 1966: plt. 43; figs. 60 a, 60 b —

Localities: 39, 57, 67

(2)	r	L	W	H	Lip	Col
Largest shell:		21.2	10.0	8.5	17	18
Smallest shell:		20.8	10.1	8.5	18	17

This species must be considered rare until additional field work can give us a true picture of its distribution in these islands. One specimen was collected at Okinawa in 1955, but no records were kept of the specific locality at the time. However, two more shells were collected by the same worker at Machinato in 1956.

Shell long, narrow, sub-pyriform; terminals heavily calloused, blunt; aperture wide, straight; teeth long and fine on base, heavy and short on outer lip; primary color off-white, dorsal area darker because of 4 wide, pale gray transverse bands, all overlaid with minute flecks of light yellow-brown; two dark brown spots at either end; base, terminals, margins, teeth, and interstices off-white.

51. *Bistolida* (*Blasicrura*) *pallidula pallidula*  
(GASKOIN, 1849)

— CATE, 1966: plt. 44; figs. 63 a, 63 b —

Localities: 41, 57, 81, 85

(2)	u	L	W	H	Lip	Col
Largest shell:		21.5	11.5	9.0	22	17
Smallest shell:		19.0	9.3	7.5	20	18

This species lives on the reef flats, usually hidden in rough, algae-covered crevices in about four feet of water; it is not often found. The solidly formed shells seem to have a thicker, more concentrated dorsal color than specimens from elsewhere.

Shell cylindrically oblong, heavy, solid; terminals heavily calloused, weakly produced; aperture nearly straight, narrow; teeth relatively fine, well defined; margins thickly calloused, right side more so, sub-angled; basic color off-white, dorsum overlaid with a thick covering of brownish-yellow flecks (the large shell, whose measurements are listed here, has a definite mantle line) that obscures the 4 broken transverse brown bands characteristic of this species; terminals, base, teeth, and interstices off-white to pale ivory.

52. *Bistolida (Blasicrura) luchuana* KURODA, 1960

— CATE, 1963: plt. 15; figs. 2, 2 a —

Localities: 14, 39, 45, 55, 57, 63 a, 65, 75 a, 85

(23)	c	L	W	H	Lip	Col
Largest shell:		21.7	13.0	10.4	20	20
Smallest shell:		16.1	9.4	7.7	18	14

This is perhaps the only species endemic to the Ryukyu Islands; as far as I have been able to determine, its range does not extend as far as the Philippines or Japan. I have examined over 75 specimens of this species and compared them with *Bistolida dayritiana* (CATE, 1963), and am convinced this latter species is not presently found in Ryukyu waters, and therefore cannot be considered as part of this molluscan fauna. At Onna *B. luchuana* is found abundantly on the submerged tide flats, most often in water just below low tide line under rocks, living in a soft, thick-stemmed, green sponge of an unidentified species. *Bistolida luchuana*, particularly at Onna, is associated with such other cypraeid species as *Ravitrona h. helvola*, *R. l. labrolineata*, *Erosaria erosa phagedaina*, *Staphylaea s. staphylaea* and *S. l. limacina*. An interesting observation is that many of the specimens of *B. luchuana* have jet-black animals, while others seem to be lighter, grey. This species has also been found at Okuma, and is never seen exposed above water due to the receding tide, as are species such as *Monetaria moneta rhomboides*, *Ornamentaria a. annulus*, and *Ravitrona c. caputserpentis*; the usual depth for this mollusk is from 3 to 7 feet. The species has also been collected on the south east coast of Miyako Is-

land (Way); SCHILDER (1962) reports a "semifossil" shell (22.5 mm.) coming from the Sukiran dredgings off Okinawa (Col. McCarty, 1955)."

Shell pyriform, lightweight; terminals strongly produced; aperture fairly wide, mostly straight, curving gently left; teeth fine, well defined, longer on rear half of base, shorter in front, labial teeth of medium length; margins well calloused, somewhat upswept and angled on the right side; basic color light-grey, 4 very pale, wide transverse bands of darker color, all overlaid with numerous, fine flecks of pale yellow-brown; a faint mantle line often present; apex depressed, dark brown; terminals, margins, base, teeth, and interstices pale ivory.

53. *Bistolida (Blasicrura) teres teres* (GMELIN, 1791)

Syn.: *Cypraea tabescens* DILLWYN, 1817 (SOLANDER MS)

Descr. Cat. Recent Shells 1: 463

*Cypraea punctulata* HIDALGO, 1907

Monogr. gén. Cypraea (M. Acad. Cien. Madrid 25: 484)

— CATE, 1966: plt. 44; figs. 66 a, 66 b —

Localities: 33, 42, 65, 71, 85

(5)	u	L	W	H	Lip	Col
Largest shell:		29.6	17.7	13.8	25	26
Smallest shell:		27.3	16.2	12.8	23	25

The shells whose measurements are recorded here were collected on a shallow-water coral outcropping at Minami. Other specimens from Smuggler's Cove, Zampa-Misaki and from Taiwan would suggest a link with the species in the Philippines and Japan.

Shell ovate to oblong-ovate, solid, heavily formed, base swollen, apex depressed; terminals produced; aperture fairly wide, curving slightly apically; teeth fine, short on base, crossing columella and long shallow fossula, somewhat larger and longer on outer lip; margins heavily calloused, angled and shouldered on right side, enveloping rear terminal; primary dorsal color pale blue-grey, overlaid with a thick pattern of light brown flecks, smudges, and a large dark brown central blotch; widely dispersed brown spots mark both margins; terminals, margins, base, teeth, and interstices off-white.

54. *Bistolida (Bistolida) kieneri depriesteri* (SCHILDER, 1933)

— CATE, 1966: plt. 44; figs. 67 a, 67 b; text fig. 1 —

Localities: 43, 53

(1)	r	L	W	H	Lip	Col
Shell measurements:		13.5	8.1	6.2	15	12

The present specimen was found among some cowries collected at Minami-Ukibaru reef on March 20, 1965. At the same time and place were also found *Melicerona felina pauciguttata* and *Purpuradusta g. gracilis*. As far as is known this is the only record of this species at Okinawa. It was collected from under a rock in about four feet of water.

Shell small, sub-pyriform, somewhat flattened; terminals inconspicuous; aperture straight, fairly wide; teeth sharp, well defined, long on rear half of base, short and restricted to columella in front, on outer lip slightly larger, of even length, almost reaching to the margin; margin thickened, sub-angled, callus very thin on the left side; primary dorsal color off-white, overlaid with 3 large dark grey areas separated by 2 irregular transverse yellow bands; 2 large dark brown spots at each terminal (quadrimaculate), small light brown spots dot the dorsum and sides; terminals, base, margins, teeth, and interstices white, except that some color pattern shows through the thin nacre covering the base.

55. *Bistolida (Bistolida) hirundo neglecta*  
(SOWERBY, 1837)

— CATE, 1966: plt. 45; figs. 68 a, 68 b; text fig. 2 —

Localities: 7 a, 33, 39 a, 57, 62 a, 81, 85

(7)	u	L	W	H	Lip	Col
Largest shell:		19.1	11.4	9.2	21	20
Smallest shell:		13.1	7.7	6.1	19	15

Especially interesting is the fact that this species has two distinctly different forms, noted in both Ryukyu specimens and in others from West Australia (CATE, 1964, p. 19). Some are long, narrow, and delicate; others are short, globose, and massive; strikingly different in appearance. Typical dimensions of both forms are reflected in the shell measurements recorded here. The shells seem to be always either one size or the other, without intermediate forms. In this instance, the larger shells were collected at Yagaji, the smaller on the tide flats at Onna. There may be other differences of a specific or subspecific character between the two forms; these only a study of the soft parts could clarify.

Shell may be relatively large or small, larger ones more cylindrical, smaller shells more pyriform; terminals prominent, apex depressed; aperture straight, narrow; margins thickened, more so on the right side, upswept, subangled, shouldered; teeth long, fine, numerous; columella and fossula denticulate; dorsum grey, divided toward the rear by a faint yellow transverse narrow band, with a larger irregular yellow mark anteriorly, the whole loosely covered with fine brown flecks; brown spots mark both margins, 2

larger dark brown spots at each terminal collar; terminals, margins, base, teeth, and interstices off-white.

56. *Bistolida (Bistolida) stolidata stolidata* (LINNAEUS, 1758)

— CATE, 1966: plt. 45; figs. 70 a, 70 b —

Localities: 7 a, 9 a, 20 a, 37, 63 a, 63 b, 65, 75 b, 81, 85

(55)	rc	L	W	H	Lip	Col
Largest shell:		28.5	15.4	12.0	22	20
Smallest shell:		23.7	13.0	10.3	19	16

In 1954-1955 this species must have been more plentiful as I have at least 55 shells collected at Okinawa during those years. On this basis I suggested (CATE, 1966, p. 263) that the Ryukyu Islands seemed to be the locality of greatest abundance for the species. Recent field experience now indicates a far less common occurrence of this species. Dredging in 1955 at Chatan (Sukiran) yielded many unusually large subfossil specimens, reflecting the earlier abundance of the species.

Shell cylindrically-rectangular, sharply angled, tapering abruptly toward terminals; apex depressed; terminals boldly exposed, semi-beaked; aperture gently curving left; teeth prominent, fairly long on both lips, but short on front half of base; margins thickened, especially so on right side where margin is upswept, angled and shouldered, with both margins becoming flanged near terminals; basic dorsal color light grey to pale beige, with a large, squarish chestnut-brown dorsal blotch; grey color bands of irregular width and shape extend from the 4 corners of the blotch to the margins, chestnut-brown stain covers margins to the terminal collars; base, teeth, and interstices white.

57. *Cribraria (Ovatipsa) chinensis chinensis*  
(GMELIN, 1791)

Syn.: *Cypraea cruenta* DILLWYN, 1817

Descr. Cat. Recent Shells 1: 460

— CATE, 1966: plt. 45; figs. 71 a, 71 b —

Localities: 9, 17, 57, 85

(6)	u	L	W	H	Lip	Col
Largest shell:		45.2	27.0	19.8	19	21
Smallest shell:		31.0	18.5	13.6	19	20

This species has been found only at two Ryukyu localities, Zampa-Misaki and Hedo. Usually it has been collected at night, although it was once found in the daytime feeding on coral outcroppings and ledges. There seems to be much variation in the size of the adult shells.

Shell ovate, heavy, strong, somewhat flattened; terminals inconspicuous, heavily formed; aperture fairly narrow, curving gently; teeth fine, well defined on base, heavy and bold on outer lip; right margin thickened, shouldered; callus covers most of right and left dorsum; dorsal area light straw-brown, with numerous off-white lacunae and an inconspicuous mantle line; sides, margins, most of base and teeth light beige, covered with numerous, various sized lavender spots; interstices bright orange.

58. *Cribraria (Cribraria) cribraria orientalis*

SCHILDER & SCHILDER, 1940

- CATE, 1966: plt. 45; figs. 72 a, 72 b -

Localities: 9 a, 33, 59, 65, 85

(18)	rc	L	W	H	Lip	Col
Largest shell:		23.0	17.4	14.0	18	20
Smallest shell:		18.9	11.3	9.3	16	18

Although several shells of this species have been collected at various localities at Okinawa, it is, nevertheless, far from common. The larger shell, whose measurements are recorded here, was trawled off Kadena, *ex* Dr. T. Shikama, probably in 1961 or 1962 (Albert).

Shell pyriform, bulbously-humped, solid, base swollen; terminals produced; aperture wide, straight, abruptly curving left adapically; margins thickened, more heavily on right side, angled, shouldered, and vaguely pitted; dorsum light yellow-brown, with numerous off-white lacunae of various sizes; terminals, margins, base, teeth, and interstices pure white.

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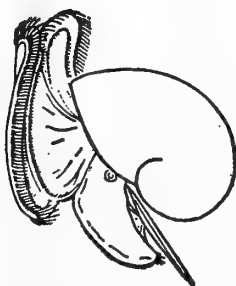
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# The Role of Behavior in Determining the Intertidal Zonation of *Littorina planaxis* PHILIPPI, 1847, and *Littorina scutulata* GOULD, 1849

BY

CARL E. BOCK

AND

RICHARD E. JOHNSON

Department of Zoology, University of California, Berkeley, California 94720

(8 Text figures)

## INTRODUCTION

*Littorina planaxis* PHILIPPI, 1847, and *L. scutulata* GOULD, 1849, are common upper littoral gastropods of the west coast of North America. *Littorina planaxis* occurs higher intertidally than *L. scutulata*, being found on the highest rocks in the splash zone. The purpose of this study was to investigate those behavioral factors which might limit the vertical distribution of both species in the vicinity of Bodega Head, California.

## HABITAT PREFERENCE

HEWATT, 1937, and RICKETTS & CALVIN, 1952, describe *Littorina planaxis* as a dominant species on the rocky intertidal Zone I (above mean higher high tide) and *L. scutulata* as characteristic of Zone II (between mean higher high and mean lower high tides). There is considerable variation in the tidal range of both species, but this undoubtedly relates to the degree of exposure and concomitant wave splash in the individual study areas. *Littorina planaxis* occurs almost exclusively on those exposed rocks which are wetted only by splash, and which are free of macroscopic algae (HEWATT, *op. cit.*; DAHL, 1964). The habitat of *L. scutulata* appears more variable. DAHL and HEWATT report it in beds of algae and also occasionally in beds of *Balanus glandula* DARWIN, 1854.

In order to determine the distribution of the two littorines at Bodega Head, we conducted counts along two transects running from the high intertidal down

through the mid-intertidal region. This spanned the ranges of both species. The results for adults and for young are plotted in Figure 1. The number of individuals was counted in each square meter along the transects, and these counts were combined into twelve equal groupings such that the two transects, although of different lengths, could be represented in a single graph.

Adult *Littorina planaxis* clearly occupy a higher position than *L. scutulata* (Figure 1). We found *L. planaxis* almost exclusively on exposed rocks wetted at high tide by splash and the larger waves. *Littorina scutulata* were most abundant in beds of macroscopic algae, especially *Pelvetiopsis limitata* (SETCHELL) GARDNER, 1910, but they were also common in high tide-pools. These pools were usually rimmed with *Gigartina papillata* (C. A. AGARDH) J. G. AGARDH, 1846, and it was here that *L. scutulata* congregated. The lower limits of *L. scutulata* came abruptly in each transect as the relatively exposed beds of algae gave way to deep pools or channels.

Curiously, almost no small *Littorina planaxis* were found, and yet the small *L. scutulata* greatly outnumbered the adults (Figure 1). Also, we found many young *L. scutulata* occurring higher up than the adults of the same species (*cf.* data in Figure 1). They were found commonly on exposed rocks along with adult *L. planaxis*. They were usually in small crevices in the rocks or packed into old *Balanus glandula* tests, as reported by HEWATT, *op. cit.*, for the Monterey coast. However, in contrast to the findings for the Monterey region, adult *L. scutulata* were not common in barnacle beds at Bodega.

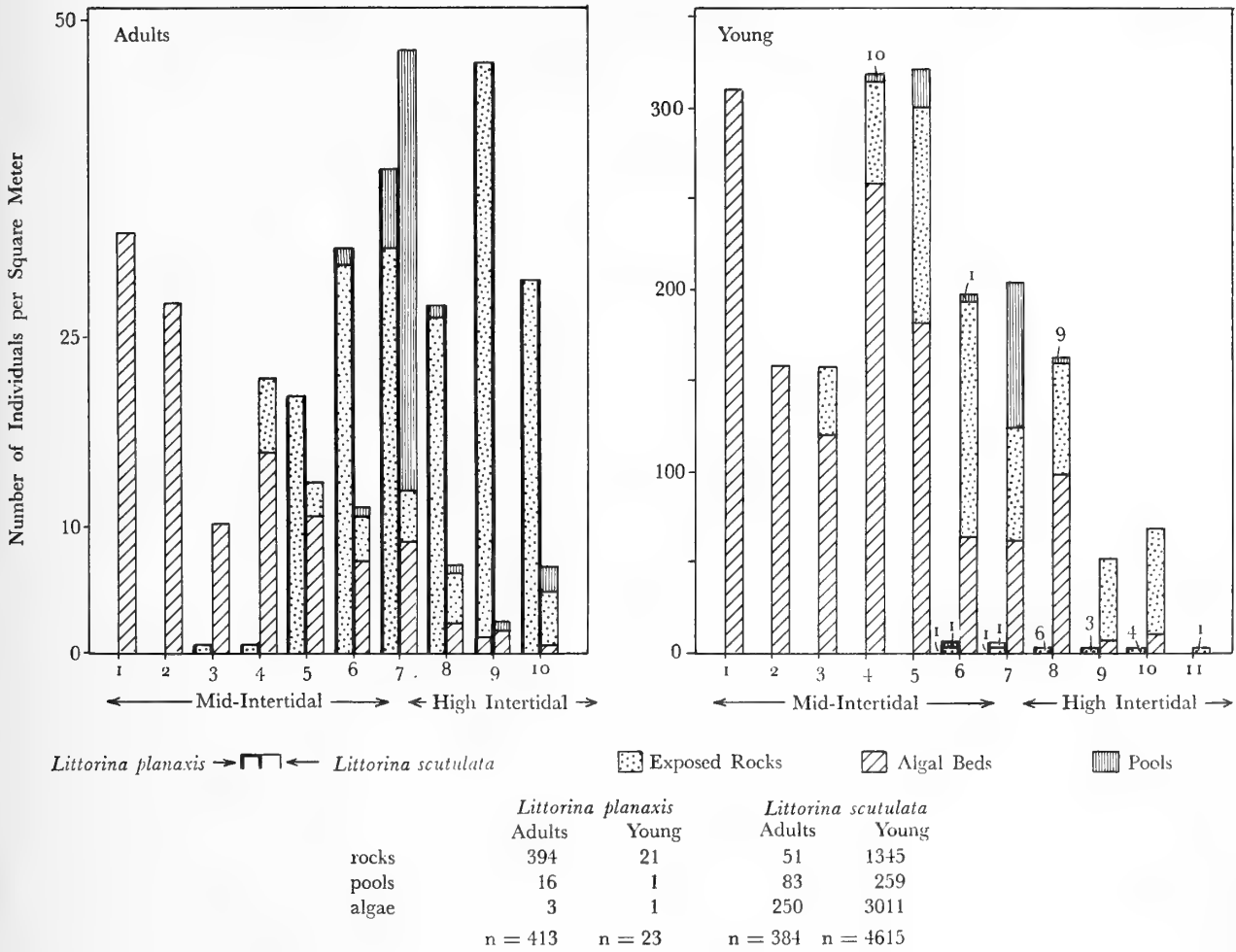


Figure 1  
Distribution of *Littorina* in the rocky intertidal area

Three types of factors could be involved in the zonation and habitat preferences of *Littorina planaxis* and *L. scutulata*. First, the physiological tolerances of the species to one or more physical parameters of the environment might act as limiting factors to distribution. Second, biotic characteristics such as predation, competition, and available food could cause one region to be preferable to another. The next section summarizes the available data on physical and biotic factors which may influence the distribution of the two littorines. While these biotic and abiotic factors must be the ultimate causes of the distribution patterns, it is possible that the behavior of the littorines prevents their movement into those areas where con-

ditions would be unfavorable. Our research centered on the third possibility and the results are presented in "Behavioral Limits to Distribution."

### POSSIBLE ENVIRONMENTAL FACTORS LIMITING DISTRIBUTION

**Desiccation:** Since *Littorina scutulata* does not occur as high intertidally as *L. planaxis*, the possibility exists that the upper limits of the former might be a function of greater vulnerability to temperature or desiccation, or both. BOWLUS, 1966, studied water loss in *L. planaxis* and

*L. scutulata*; all animals were held in dry containers at temperatures varying from 29.4° C to 32.2° C. At 100 hours *L. scutulata* had begun to die and by 127 hours 70% were dead. In the same time period, none of the *L. planaxis* had died, and they lost much less body water. *Littorina planaxis* secretes a mucous seal between the shell and substrate when exposed to dry conditions. We did not observe this response in *L. scutulata*, but it undoubtedly would help prevent water loss. HEWATT, *op. cit.*, recorded 100% survival of *L. planaxis* above the highest wave splash for at least 64 days. BARKMAN, 1955, gathered similar data for many littorines and was able to correlate, in a general way, desiccation tolerance with the degree of periodic exposure experienced by each species.

Although it appears that *Littorina planaxis* is more resistant to high temperatures and dry conditions than is *L. scutulata*, we shall show that the behavior of the latter protects it from these circumstances.

**Submersion:** RICKETTS & CALVIN, *op. cit.*, state that *Littorina planaxis* will "ultimately drown" if held under water. Many species of high intertidal periwinkles, including *L. planaxis*, have relatively degenerate ctenidia and a vascularized mantle epithelium, both of which favor oxygen exchange in air (NICOL, 1960). Thus drowning or at least respiratory inefficiency under water may be a factor controlling the lower limits of distribution in *L. planaxis*.

**Fresh Water:** Since *Littorina planaxis* occurs higher than *L. scutulata*, and since considerable rainwater can accumulate in the high intertidal, it might be expected that the former species would be more tolerant to fresh water. In the laboratory, we found only one percent mortality in *L. planaxis* after 3 days submersion in tap water ( $n=100$ ), while 65% of the *L. scutulata* died in 2 days. Seventy-five percent of these had burst from their shells, presumably due to osmotic stress. Water circulation was maintained during the experiment. BARKMAN, *op. cit.*, in

a survey of other littorine studies, found that species which occupy the upper zones tend to have greater fresh water tolerances.

**Hypersalinity:** In the summer, the highest tide-pools at Bodega Head become hypersaline between spring tides due to evaporation. Although we have no experimental data regarding tolerances, littorines are absent from many of these pools. We have found *Littorina scutulata* common in pools with salinities up to 104% sea water, only rarely in those of 110%, and not at all in pools of about 140%.

**Competition and Predation:** The behavioral experiments described in the following section suggest that competition is not the immediate cause of behavioral zonation, since both *Littorina planaxis* and *L. scutulata* selected their respective habitats in the absence of one another. Nevertheless, this does not rule out the possibility that competition in the past has resulted in selection for such behavioral responses.

*Littorina planaxis* occurs above the predatory snail *Thais emarginata* (DESHAYES, 1839) in the intertidal, but there is no evidence to suggest that this results from predatory exclusion.

**Food:** DAHL, *op. cit.*, noticed that *Littorina planaxis* occurred largely on high exposed rocks with encrustations of microscopic algae, while *L. scutulata* were common at lower levels in beds of macroscopic forms; however, it remains unclear whether this apparent difference in food preference is a cause or result of differences in zonation. DAHL did find that *L. planaxis* were unwilling or unable to feed on the large algae unless the fronds were chopped into small pieces; this suggests that food might be a zonation factor, at least for this species.

Table 1 summarizes those environmental factors which may be involved in controlling the limits of distribution in the two littorines.

Table 1

Possible Environmental Factors Controlling the Distribution of *Littorina*

	Upper Limits	Lower Limits
<i>Littorina planaxis</i>	<ol style="list-style-type: none"> <li>1. permanent desiccation above splash zone</li> <li>2. lack of algae as food above splash zone</li> </ol>	<ol style="list-style-type: none"> <li>1. possible respiratory inefficiency during submersion</li> <li>2. possible lack of microscopic algae as food</li> <li>3. possible predation</li> <li>4. possible competition</li> </ol>
<i>Littorina scutulata</i>	<ol style="list-style-type: none"> <li>1. desiccation on exposed rocks</li> <li>2. fresh (rain) water on exposed rocks</li> <li>3. hypersaline waters of highest pools</li> <li>4. lack of macroscopic algae for food</li> </ol>	<ol style="list-style-type: none"> <li>1. possible lack of suitable foods</li> <li>2. possible respiratory inefficiency during submersion</li> </ol>

## BEHAVIORAL LIMITS TO DISTRIBUTION

## Field Studies

In attempting to evaluate the role of behavior in the distribution of *Littorina planaxis* and *L. scutulata*, we carried out a field experiment at Doran Beach involving transplantation of marked animals. Region 1 (Figure 2) encompassed a small tide-pool rimmed with *Gigartina*, and ran up about 2 m onto an exposed rocky shelf. *Littorina scutulata* were common in and around the pool while *L. planaxis* occurred on the rock face above. We placed 75 *L. planaxis* and 50 *L. scutulata* (marked with red or

yellow enamel) in the pool and equal numbers up on the rocks. This is the situation represented at day one in Figure 2. Region 2 (Figure 3) was similar except that the exposed rock face gave way to an extensive bed of *Pelvetiopsis* instead of a tide-pool. Also, region 2 experienced a much greater wave splash during high tides.

Since our habitat work showed that *Littorina planaxis* was common on exposed rocks while *L. scutulata* occurred in pools and beds of algae, we felt that the outcome of this experiment would indicate the possible role of movement in zonation. If the littorines segregate according to habitat, those *L. planaxis* placed high should remain there, while those placed in pools (region 1) or algae (region 2) should

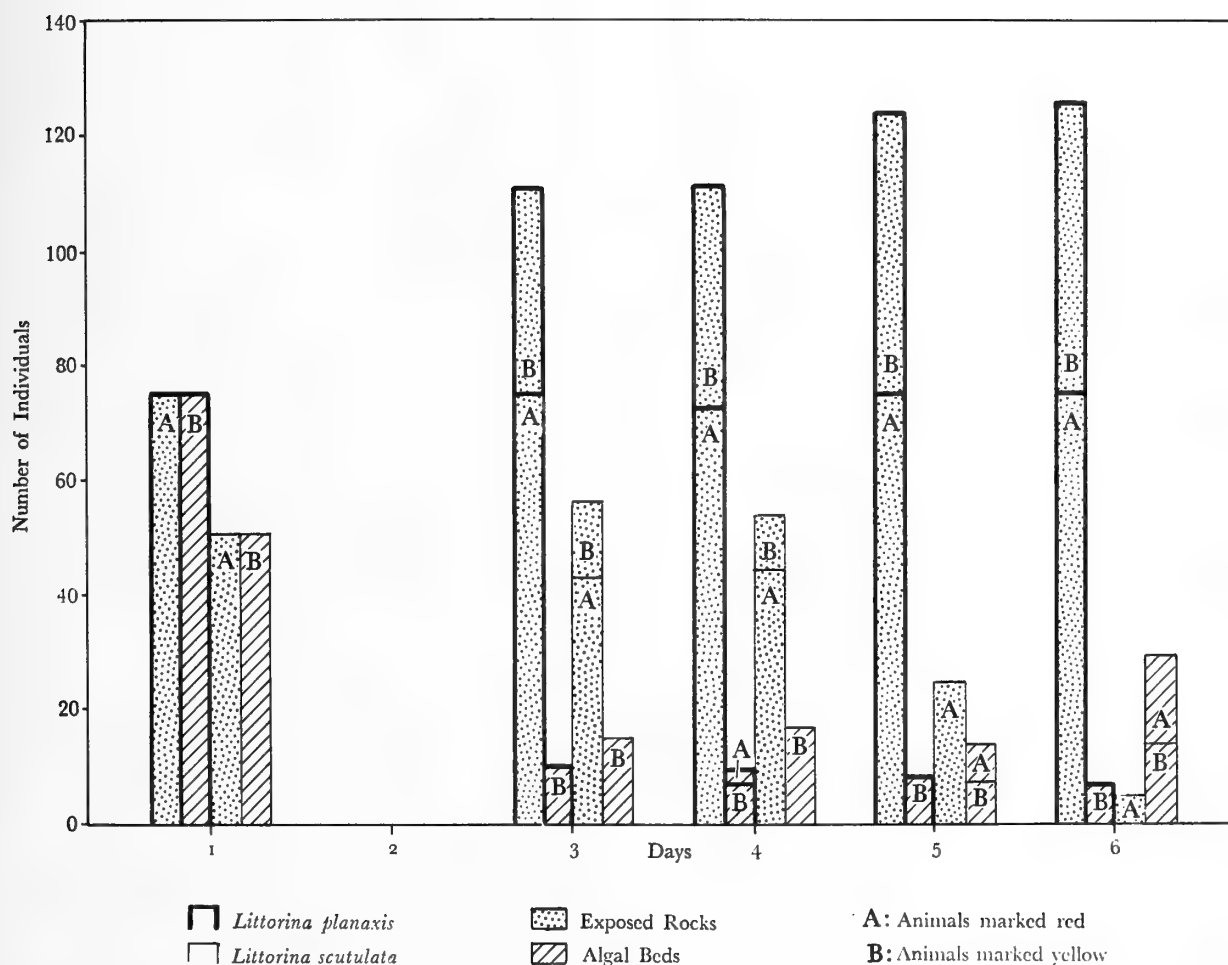


Figure 2

Doran Beach. Habitat selection study, region 1

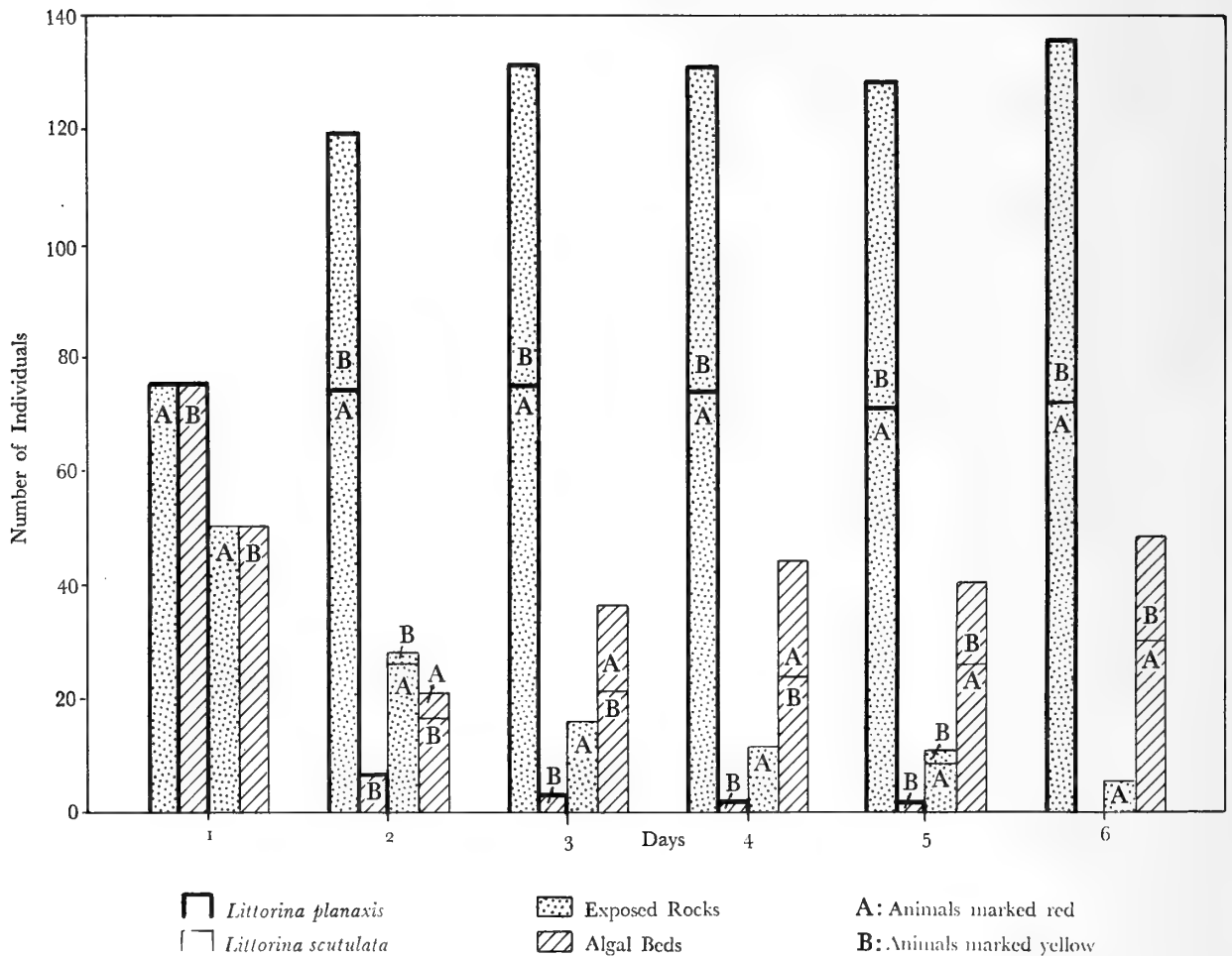


Figure 3

Doran Beach. Habitat selection study, region 2

move up to the exposed rocks. The reverse would be expected for *L. scutulata*. Results (Figures 2 and 3) show that this is essentially what happened, and we conclude that behavioral zonation occurs.

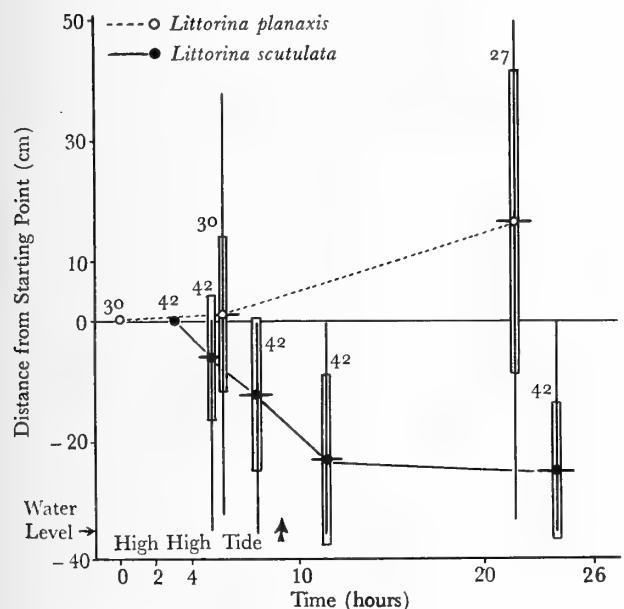
*Littorina planaxis* moved up rapidly in both areas, although a small percentage was apparently swept away before becoming established. The behavioral response of *L. scutulata* was not as immediate. Also, a larger percentage was washed away; both those placed on exposed rocks and those in pools or algae were lost. It is highly significant that the downward trend of *L. scutulata* was slower in region 1 than in region 2 (cf. Figures 2 and 3).

We attribute this to the combined effects of voluntary downward movement and involuntary movement due to heavier wave shock in the latter region. *Littorina scutulata* were easily dislodged from the high rock by wave action; they then tumbled down into the *Pelvetiopsis*. The response in region 1 represents largely behavioral movement alone, as this region was protected from strong wave action.

We next conducted a series of experiments at Bodega Head, designed to analyze in more detail the responses of *Littorina* when placed in a variety of habitats. These experiments are represented in Figures 4 through 7, and

involve distances traveled by each species in relation to the tide cycle. Each species was tested separately in order to prevent possible interactions. Snails were marked with enamel and counted periodically during the trial without being removed from the substrate.

1. Thirty *Littorina planaxis* and 42 *L. scutulata* were placed about 35 cm above the surface of a high tide-pool on an exposed rock (Figure 4). Although *L. planaxis*



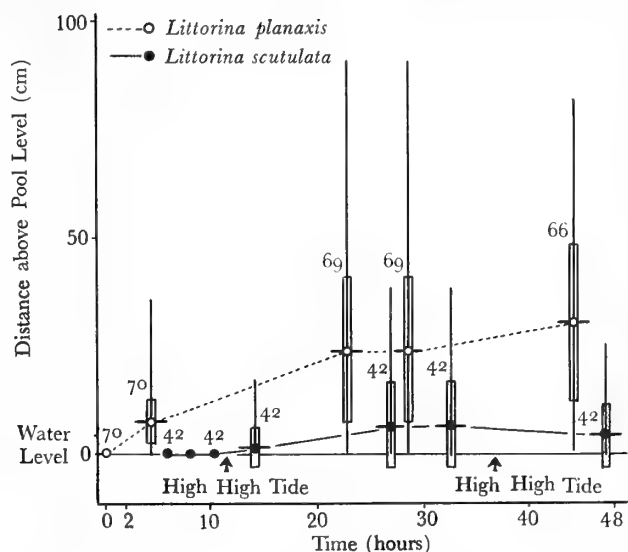
Horizontal Line:  $\bar{x}$  Vertical Line: Range Rectangle:  $\pm 1$  s.d.

Figure 4

Movement of *Littorina* placed above a high tide-pool

moved in all directions (range: -33 cm to +56 cm), they averaged 16.8 cm higher on the rock after 22 hours. In *L. scutulata* there was an obvious downward movement, averaging 25.3 cm below the starting point after 24 hours. This position was only about 7.6 cm above water level; the majority of the snails came to rest on the *Gigartina* around the lip of the pool. This difference is highly significant at the 0.01 probability level, using a two-sided "t"-test for differences of means, and indicates a movement of *L. scutulata* down towards the pools in the high intertidal.

2. Figure 5 shows the results of a related experiment in which 70 *Littorina planaxis* and 42 *L. scutulata* were set in the bottom of a tide-pool. All animals in the pool were given the value zero cm. After 48 hours, *L. scutulata*



Horizontal Line:  $\bar{x}$  Vertical Line: Range Rectangle:  $\pm 1$  s.d.

Figure 5

Movement of *Littorina* placed in a high tide-pool

averaged 7.26 cm above pool surface, very comparable to the position of this species in the first experiment; during the same period, *L. planaxis* moved up an average of 32 cm. Again, *L. scutulata* selected the pool rim, while *L. planaxis* moved out on the exposed rocks. It is significant that movements ceased when the rocks were dry between higher high tides (Figure 5).

3. In the two preceding experiments, we demonstrated behavioral differences between the two littorines in the high intertidal. The final two experiments were conducted at the lower limits of distribution. First, we placed 45 *Littorina planaxis* and 55 *L. scutulata* on a rock slope with scattered algae. This was within the normal range of *L. scutulata*. The results (Figure 6) show a significant (to 0.01 level) upward movement of *L. planaxis* when compared to the other periwinkle. We interpret this as evidence of *L. planaxis* seeking its preferred, higher, intertidal position. Note here that the movement occurred between high tides rather than during them. The snails clung firmly in place during the periods of wave shock.

4. The final experiment was carried out at a level comparable to that of the last, but on an exposed point subject to very heavy splash and surge; macroscopic algae were lacking. Here both species moved up to a higher

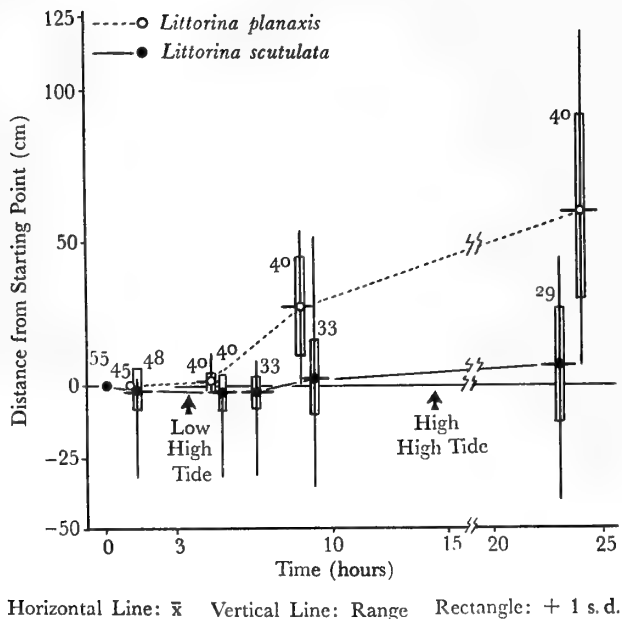


Figure 6

Movement of *Littorina* placed in a bed of macroscopic algae

position (Figure 7); there was no significant difference in means at the 0.05 level. This area, then, was apparently below the preferred habitat of either species.

We noticed in the Doran Beach study that *Littorina scutulata* were more easily dislodged than *L. planaxis*. Data from the last series of experiments support this and suggest two ways in which the latter is better adapted. First, when *L. scutulata* become dry on an exposed rock, instead of fastening on with a mucous seal as *L. planaxis*, they come to lie with opercula facing up and the shell attached by only a thin strand of mucus. In this position, *L. scutulata* are easily dislodged. Splash thus accounted for a considerable proportion of the downward movement of *L. scutulata* in the first experiment (Figure 4).

Second, in the two experiments concerning exposed lower areas, 13% of 69 *Littorina planaxis* were swept away while 41% of 79 *L. scutulata* were lost. Since these areas were continuously moist, the snails did not withdraw into their shells, but simply clung to the rocks. It would appear that *L. planaxis* is better able to do so, although NORTH, 1954, found relative foot size to be comparable in both species. NORTH found that greater numbers of *L.*

*planaxis* were lost from a rock which he washed through a tide-pool. Our data, collected under more natural conditions, suggest a greater resistance to wave shock in *L. planaxis* – certainly an essential adaptation for life on exposed rocks.

In summary, *Littorina planaxis* and *L. scutulata* apparently occur in their respective habitats largely because of differences in behavior.

We found *Littorina planaxis* will move up out of pools or beds of macroscopic algae; thus these constitute the lower limits of their distribution. WILLIAMS, 1950, found he could induce *L. planaxis* to move higher than they normally occur in the field by artificially wetting the substrate. This suggests that these snails will move as high as there is wave splash. WILLIAMS reports that *L. planaxis*

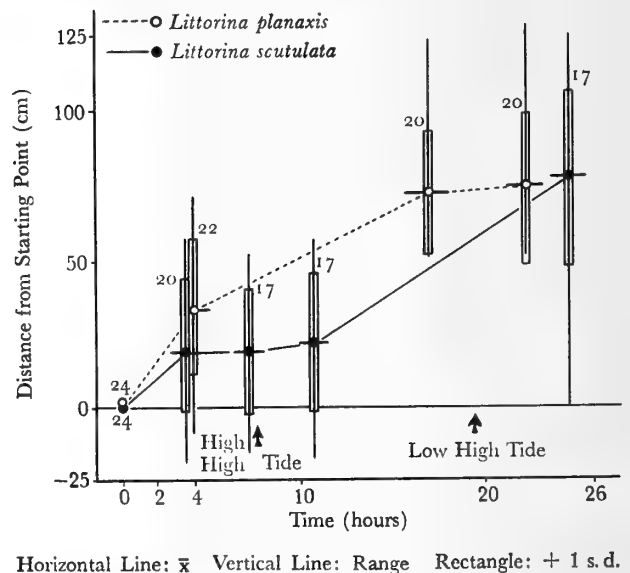


Figure 7

Movement of *Littorina* placed on a low intertidal rock

will move back down from a high position if they have experienced a period of desiccation. Thus it may be that populations fluctuate with the high tide levels. *Littorina scutulata* avoids both high rocks and lower areas by selecting pools and beds of algae in the mid-intertidal.

EVANS, 1961, attributed behavioral zonation in *Littorina punctata* FERRUSAC, 1821, to a combination of geotaxis

and orientation to the shore. BARKMAN, *op. cit.*, and NEWELL, 1958 a, 1958 b, considered gravity, light, tidal fluctuations, and preference for certain algae to be involved in the zonation of *L. obtusata* FERRUSAC, 1821, and *L. littorea* FERRUSAC, 1821. In the following section we have attempted to evaluate the role of various environmental stimuli which might affect the behavior of *L. planaxis* and *L. scutulata*.

### Laboratory Studies

**The Role of Algae:** In the field adult *Littorina scutulata* are most abundant on *Pelvetiopsis limitata*, somewhat less common on *Gigartina papillata*, and occur only rarely on other species of algae. At least two explanations for this distribution are possible. *Littorina scutulata* may choose certain species of algae in preference to others or they may choose a certain intertidal level regardless of the type of algae present. Three sets of experiments were set up to test the first alternative.

1. An aquarium (33×53×127 cm) was set up following the procedure of BARKMAN, *op. cit.*, and VAN DONGEN, 1956. There was only a shallow layer of water

on the bottom which ran from an inlet at one end to an outlet at the other. One species of algae was placed at the inlet with a concrete block placed on each side to prevent the algae from washing down the aquarium (*cf.* diagram in VAN DONGEN). One hundred *Littorina scutulata* were placed 41.5 cm downstream from the algae. Controls were run in which no algae were present. All trials lasted for 12 hours and each of the 4 species of algae was run twice. The bottom of the tank was scrubbed after each run to prevent the periwinkles from detecting the scent of algae or their own mucus trails. Results were recorded in 4 categories: those snails which were on the algae, those that moved upstream but were not found on the algae, those which remained in the starting area, and those which moved away.

Results of this experiment (Table 2) show that *Littorina scutulata* moves toward *Gigartina* and *Pelvetiopsis* in greater numbers than toward *Iridophycus flaccidum* SETCHELL & GARDNER, 1937, and toward the latter in greater numbers than toward *Prionitis lanceolata* HARVEY, 1853. These differences are all significant at greater than the 0.001 level by the chi-square test. There was no significant difference between *Pelvetiopsis* and *Gigartina*. The number moving upstream but not found on the algae remained

Table 2

Attraction of *Littorina scutulata* to Single Species of Algae when Placed Down-Stream from the Algae

	Up-Current		Central	Down-Current	Total
	on algae	not on algae			
Control:					
trial 1	0	35	41	24	100
trial 2	0	41	27	32	100
Total	0	76(38%)	68(34%)	56(28%)	200
<i>Pelvetiopsis limitata</i>					
trial 1	44	32	8	15	99
trial 2	30	50	1	19	100
Total	74(37%)	82(41%)	9( 5%)	34(17%)	199
<i>Gigartina papillata</i>					
trial 1	34	34	9	16	93
trial 2	32	46	9	13	100
Total	66(34%)	80(41%)	18( 9%)	29(15%)	193
<i>Iridophycus flaccidum</i>					
trial 1	14	45	31	7	97
trial 2	23	34	13	22	92
Total	37(20%)	79(42%)	44(23%)	29(15%)	189
<i>Prionitis lanceolata</i>					
trial 1	5	31	9	52	97
trial 2	8	77	2	15	102
Total	13( 6%)	108(54%)	11( 5%)	67(34%)	199

nearly constant throughout the runs except in the *Prionitis* tests. For unknown reasons the second of the two *Prionitis* runs differed significantly from the first and caused this upstream non-algae value to be high.

When no algae were present, 38% of the *Littorina scutulata* moved upstream; when algae were present, 60% or more moved upstream except in the one run using *Prionitis*.

2. The second set of experiments, similar to another series carried out by BARKMAN, *op. cit.*, and VAN DONGEN, *op. cit.*, was conducted on the bottom of two large tanks, each of which had a shallow layer of water running over the bottom. One hundred *Littorina scutulata* were placed on the bottom in the center and four patches of algae were each placed at 15 cm distance from the *L. scutulata*. At the end of 12 hours the number of animals on each species of alga was recorded, the bottom of the tank scrubbed, and the four algal species were rotated 90° so that after four trials each species had been in each position, thus eliminating any effects caused by unequal lighting, etc., on the tank floor.

*Gigartina* and *Pelvetiopsis* attracted the greatest number of periwinkles (Table 3), *Iridophycus* was second,

Table 3

Selection of Algae by *Littorina scutulata*  
When Four Species of Algae are Presented Simultaneously

	<i>Iridophycus</i>	<i>Pelvetiopsis</i>	<i>Gigartina</i>	<i>Prionitis</i>	Wall	Total
Tank 1	21	38	16	3	20	98
	12	32	44	4	6	98
	9	15	36	24	11	95
	32	7	28	7	15	89
subtotal	74	92	124	38	52	380
Tank 2	35	30	15	1	15	96
	29	13	8	22	28	100
	11	33	30	13	13	100
	16	21	17	17	28	99
subtotal	91	97	70	53	84	395
Total	165	189	194	91	136	775
Percent of algae:	25.8	29.6	30.4	14.2		

and *Prionitis* was last. The difference between the first three and *Prionitis* was significant at the 0.001 level, but

there was no significant difference between the first three. Nonetheless the order of preference was similar to that of the first experiment.

3. In the third set of experiments two sheets of clean glass (22×52 cm) were placed in a small aquarium (30×38×61 cm) such that they formed a V at the bottom; the slope of each was 37° from the horizontal. An 8 to 10 cm band of a single species of alga was held on the upper surface of each plate 3 cm below the surface by a thread around each plate. In the absence of the algae, periwinkles placed under water in the V would climb out of the water to the top of one of the glass plates. However, with the algae present as described they would congregate on the algae, at least temporarily, rather than continue up the plate. Between 60 and 70 individuals were tested separately for each of four species of algae. After one hour the number of animals on the algae and above it was recorded, the glass plates were scrubbed, and fresh animals were started at the bottom.

*Pelvetiopsis* retained the greatest number of *Littorina scutulata* beneath the water (71%), *Gigartina* and *Iridophycus* were second (36 and 42%), and *Prionitis* was third (18%). The results are similar to the preceding experiments except that *Gigartina* dropped to second place with *Iridophycus*. The difference between *Pelvetiopsis* and the second two is significant to the 0.001 level, and between these two and *Prionitis* to the 0.01 level by the chi-square test.

The results of these three experiments show that the four algae are probably preferred by *Littorina scutulata* in the order: *Pelvetiopsis*, *Gigartina*, *Iridophycus*, *Prionitis*. On Bodega Head, *L. scutulata* was found on nearly every patch of *Pelvetiopsis* that we observed. *Gigartina* appeared to be occupied only when it was found at levels comparable to *Pelvetiopsis*, or when it was lining tide-pools. It was commonly found at lower levels and in more exposed sites without any periwinkles on it. *Iridophycus* was lower than *Pelvetiopsis* in the field, and *L. scutulata* was present on it only in those unusual locations where it occurred high. *Prionitis* was found in tide-pools and it only rarely had adult periwinkles on it.

When *Littorina scutulata* were placed in an aquarium the majority would quickly climb out of the water. Our laboratory experiments above have shown that the presence of *Pelvetiopsis* in the water will keep these animals below the water line. *Gigartina*, while preferred over the remaining two species of algae when at the surface, was not effective in keeping the periwinkles beneath the water; this might explain why *Gigartina* lacks periwinkles when it occurs low intertidally.

In order to test the effects of the interaction between water level and algae on the position of *Littorina scutulata*,

the third experiment was modified. In this case the algae formed a 20 cm band extending equally above and below the water line. Color-marked individuals were placed in the bottom of the V, and their locations with respect to the water line were recorded every 1 or 2 hours, except during 8 hours of darkness each night. These figures were converted to an estimated time spent above or below water line on the algae (a separate set of experiments, testing the effect of tidal action independent of the position of macroscopic algae, will be described later).

It was found that all individuals (15) remained on the algae for the 75 hour duration of the study; most moved up and down, entering and leaving the water several times, but 3 apparently remained well above the water line throughout the test. *Littorina scutulata* were above the water 59% of the time, below 21% and at the water line 20%. This indicates that *L. scutulata* retains the tendency to move up out of the water when on *Pelvetiopsis* but that they will remain in the water rather than leave the algae.

These experiments indicate that *Littorina scutulata* select both the level and the species of algae on which they occur. BARKMAN, *op. cit.*, found a similar situation for *L. obtusata*.

On Bodega Head small (2-6 mm) *Littorina scutulata* occur in large numbers in tide-pools on *Prionitis lanceolata*, but adults are rarely found in this situation. Consequently we repeated the "V-glass" experiment with 77 young *L. scutulata* using *Prionitis* on the glass below water level. The results of this study showed that 79% of the young remained submerged for at least 1 hour on *Prionitis*, while only 18% of the adults did so.

Since *Littorina planaxis* is normally found above the level of macroscopic algae, the third experiment (V-glass) tried on *L. scutulata* was rerun on *L. planaxis*. Whereas *Pelvetiopsis* was sufficient to keep 71% of the *L. scutulata* beneath the water for an hour, it retained only 17% of 69 *L. planaxis* tested.

DAHL, *op. cit.*, has shown that *Littorina planaxis* will feed on chopped-up macroscopic algae, but rarely on whole fronds. He suggested 3 reasons for this behavior: (1) *L. planaxis* prefers a more stable substrate, (2) they are unable to bite off pieces of whole algae, (3) "most macroscopic algae are somehow chemically disagreeable." He eliminated the third possibility, since the snails did consume the chopped-up macroscopic algae. DAHL found that there were no obvious differences in the radulae of the two littorines, which makes the second reason unlikely. Therefore the type of substrate may be the stimulus to which *L. planaxis* responds. Apparently *L. planaxis* will continue to crawl upwards until it locates a suitable, (*i. e.* stable) substrate on which to feed.

In summary, *Littorina scutulata* display a strong negative geotaxis while in water; this is suppressed in the presence of certain preferred species of macroscopic algae. *Pelvetiopsis* is preferred by adults and *Prionitis* by young. The snails can distinguish the various species of algae and show a definite order of preference. Negative geotaxis continues in effect while *L. scutulata* is submerged; this tends to move the periwinkles to the highest macroscopic algae, which are usually also the preferred species. In contrast, *L. planaxis* displays a strong negative geotaxis which is not suppressed in the presence of macroscopic algae. Its usual food is microscopic encrusting forms occurring high intertidally.

**Tidal Action:** It has been shown in the laboratory that the presence of certain species of macroscopic algae will cause a separation in vertical location of *Littorina planaxis* and *L. scutulata*; however, other factors, such as tide, may also play a role in determining the separation seen in the field. In order to determine in the laboratory whether fluctuating water level alone would cause a separation of the two species, a large aquarium (113×113×179 cm) was set up in which water level was periodically raised and lowered. The "high tide" was 72 cm above the bottom and the "low tide" was 30 cm up, making a total range of 42 cm.

Both species were found over a wide range of heights (Figure 8), but it will be seen that there was an immediate separation of over two standard deviations between the average positions of the two species. *Littorina scutulata* occurred mainly around the mean "high tide" line. *Littorina planaxis* climbed higher out of the water and the majority was found at the top of the tank, where an overhanging lip kept them from moving higher. Neither species made vertical migrations with the artificial tides. *Littorina scutulata* became active each time the water reached their level, but most of the *L. planaxis* were a considerable distance above the water and remained dry and inactive.

**Geotaxis:** It has already been mentioned that both *Littorina planaxis* and *L. scutulata* climb up out of water when placed in an aquarium. Also we noted that certain species of macroscopic algae will override the negative geotaxis in *L. scutulata*, but that this geotaxis is still present, acting to move the animals up to the highest algae.

Since *Littorina planaxis* will continue to crawl upwards after leaving the water, it seemed likely that some environmental cue must prevent them from continuing to crawl up away from the ocean. In the field we noted that they would not continue to move up on dry rock and seemed to limit their activities to periods when the rocks were wet from the spray of high tide.

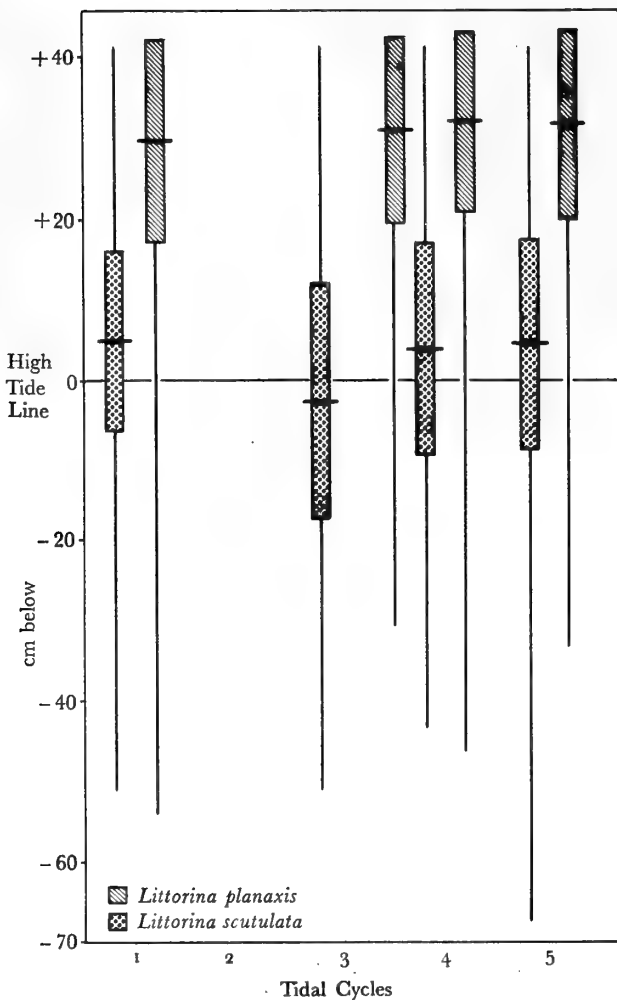


Figure 8

Movement of *Littorina* placed on bottom of tank with fluctuating water level

In the laboratory we found that *Littorina planaxis* would climb out of water and up a warm, dry glass surface as far as they were able to carry enough water with them to keep the glass moist. Those animals placed directly on a warm, dry surface closed up and did not move down. However, those animals that moved up from water onto a dry surface would turn and move down the glass if a blast of hot dry air from a hair dryer were directed toward them. A blast of cool air did not have this effect. Heating the glass ahead of the animal from

the underside would also cause the snail to reverse directions and go down. Thus, a reversal of negative geotaxis in *L. planaxis* can be elicited when an animal climbing above water encounters unfavorable temperatures. Also, an animal desiccated for a considerable time will move down when rewetted. Studies by other workers have shown that many species of *Littorina* exhibit reversals of geotaxis after desiccation (BARKMAN, *op. cit.*; NEWELL, *op. cit.*; JANSSEN, 1960; EVANS, *op. cit.*).

**Light:** Since *Littorina planaxis* and *L. scutulata* occur at different tidal levels, it seemed possible that their response to light might be one of the controlling factors. Eighty-seven *L. planaxis* and 85 *L. scutulata* were tested 3 times each for light response, using the same small aquarium and sloping glass plates which were employed in the third of the experiments with algae. A 100 watt bulb was placed at one end of the aquarium so that an animal climbing the glass plates would either be going directly toward the light or away from it. The light intensity varied from 400 foot-candles at the top of the nearest glass plate to 12 foot-candles toward the far end of the aquarium. *Littorina planaxis* proved to be strongly photonegative but *L. scutulata* was only slightly so (Table 4). We obtained similar results using 86 young *L. scutulata*. Smaller samples of each species were tested on a horizontal glass plate in the aquarium; results were similar.

Table 4

Responses to Light  
by *Littorina planaxis* and *Littorina scutulata*

	<i>Littorina</i> <sup>1</sup> <i>planaxis</i> (adult)	<i>Littorina scutulata</i> <sup>1</sup> (young) (3½-6 mm)	(adult) (10- mm)
+++	2	10	13
++—	1	24	14
+— —	13	29	32
— — —	71	23	26

<sup>1</sup> Numbers of individuals falling into each of the possible categories of response. + = movement towards, — = movement away from light. Each symbol equals one experiment and each animal was tested three times.

The experiments on sloping glass were rerun using strong natural light (15000 foot-candles) shining in at a similar angle and the results were practically identical to those with the weaker light. All experiments were run at water temperatures between 14 and 15° C.

The strong photonegative response of *Littorina planaxis* does not prevent it from moving up in the intertidal zone.

However, this species is found clustered in cracks and crevices, and light may be the stimulus causing this. Such behavior would likely be of survival value by reducing desiccation, heating, and predation. *Littorina scutulata* may show a weaker photonegative response because, in its more protected and wet location, a strong response would be of little value. However, the response may be sufficient to drive some animals under the protection of algal fronds.

Apparently most species of *Littorina* have distinct light responses, but these are not always correlated in any obvious way with behavior in the field (BARKMAN, *op. cit.*; NEWELL, *op. cit.*; JANSSEN, *op. cit.*; CHARLES, 1961 a, 1961 b, 1961 c).

Behavioral responses controlling distribution of *Littorina planaxis* and *L. scutulata* are summarized in Table 5.

Table 5

Behavioral Responses Controlling Distribution of  
*Littorina planaxis* and *Littorina scutulata*

	Upper Limits	Lower Limits
<i>Littorina planaxis</i>		
Reversal of Geotaxis	Negative Geotaxis	
1. on reaching high temperatures	1. when under water	
2. when rewetted after desiccation	2. when on macroscopic algae	
<i>Littorina scutulata</i>		
Negative Geotaxis suppressed by preferred species of algae	Negative Geotaxis	

## SUMMARY AND CONCLUSIONS

1. *Littorina planaxis* and *L. scutulata* are common periwinkles of the rocky coast of California. *Littorina planaxis* occurs very high intertidally, usually on exposed rocks in the splash zone. *Littorina scutulata* is found largely in mid-intertidal areas, frequently in beds of macroscopic algae and pools rimmed with algae.

2. The physiology and food habits of each species are correlated with these differences in habitat. *Littorina planaxis* is more tolerant of desiccation, temperature, and fresh water, — conditions encountered more often in the high intertidal. *Littorina scutulata* readily consumes macroscopic algae, while *L. planaxis* apparently will take only microscopic encrusting forms.

3. Although tolerances to environmental conditions ultimately must determine the distributions of *Littorina planaxis* and *L. scutulata*, selection apparently has resulted in behavioral responses which cause avoidance of these limits. *Littorina planaxis* moves up in the field, acting under a strong negative geotaxis. It thus congregates in the highest portions of the splash zone. *Littorina scutulata* shows a similar upshore orientation which keeps it out of low intertidal areas, but this behavioral response is negated by the presence of certain macroscopic algae in the mid-intertidal.

## ACKNOWLEDGMENTS

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# Preliminary Observations on the Feeding Behavior of *Conus purpurascens* BRODERIP, 1833

BY

JAMES NYBAKKEN

Department of Biological Sciences, California State College at Hayward, Hayward, California 94542  
and

Moss Landing Marine Laboratories, Box 223, Moss Landing, California 95039<sup>1</sup>

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(Plate 4)

AT LEAST TWO SPECIES of the genus *Conus*, *Conus striatus* LINNAEUS, 1758, and *C. catus* HWASS in BRUGUIÈRE, 1792, are known to prey on living fishes (KOHN, 1956). Both are Indo-West Pacific in distribution. Until now no species of the West American *Conus* fauna has been reported in the literature as preying on fishes. This paper reports on the feeding of *C. purpurascens* BRODERIP, 1833 on fishes under captive conditions.

During the summer of 1966, while I was initiating a study of the ecology of the West American species of *Conus* in the Guaymas area of western Mexico, four specimens of *C. purpurascens*, together with representatives of 7 other West American *Conus* species, were collected and brought alive to aquaria at the Moss Landing Marine Laboratories. In an effort to maintain these specimens alive, I contacted Dr. Alan Kohn who stated, from observations of Dr. R. T. Paine, that *C. purpurascens* was a fish eater. I therefore attempted to feed local fishes to the captive specimens with the aim of studying the feeding process itself. A few preliminary results of these studies, primarily in the form of a sequence of photographs of the feeding process, have been obtained and are reported here.

## METHOD AND RESULTS

A one gallon aquarium was set up near a window in my office so that illumination would be sufficient for photography. The aquarium had a bottom substrate of sand and was filled with sea water having a temperature

near that of the large holding tank (about 22° C). Each feeding sequence was either observed and notes taken or it was the subject of a photographic record.

Only two species of fishes have as yet been used in the experiments, *Xerorpes fucorum* (JORDAN & GILBERT, 1880) and *Oligocottus snyderi* GREELEY, 1901. Both species have been taken without hesitation by all four captive specimens of *Conus purpurascens*. More species of fish are being tested.

For each observation the specimen of *Conus purpurascens* was removed from the holding tank and placed into the experimental aquarium. Shortly after placing the *Conus* in the tank a fish was netted out of the fish holding aquarium and placed into the experimental aquarium with the *Conus*.

In general the sequence of events observed in the feeding was similar to that outlined by KOHN (1956) for *Conus striatus*.

When placed into the isolation aquarium from the holding tank, *Conus purpurascens* shows little movement for several minutes. Then the siphon is extended and moved slowly around. If the animal is left alone in such circumstances, after about 10 minutes it extends out from its shell and begins to burrow down into the sand. The usual inactive position of this species in aquaria is partially or totally buried in the sand with only the siphon protruding above the surface.

If, however, a fish is introduced into the aquarium its presence is sensed by the *Conus* almost immediately. KOHN (1956) has suggested that *Conus striatus* detects the presence of fish by chemoreception using the osphradium. This would appear to be the mechanism acting in

<sup>1</sup> Contribution No. 6 from Puerto Peñasco Marine Research Station

*Conus purpurascens* also. I tested this by adding to the *Conus* tank water taken from the fish holding tank. This prompted immediate activity on the part of two *Conus* individuals indicating use of chemoreception to sense the presence of the fish.

The animal responds to the presence of the fish by extending its proboscis (Plate 4, Figure 2). The proboscis is orange-red in color on the dorsal side and flesh color on the ventral side. The orange-red color is particularly striking in an animal which otherwise has a subdued purple or brownish coloration. The proboscis may extend out as far as one to one-and-a-half times the shell length. The proboscis is waved around or else moved along the substrate in search of the fish (Plate 4, Figure 2). Often a combination is used. The exact method of location of the fish by the proboscis is unknown as yet, but it appears in some cases as if it were accidental. In no instance observed did the proboscis follow a direct route to the fish.

Once the proboscis tip touches the fish (Plate 4, Figure 3) there is occasionally a slight retraction away from the fish followed by a second contact. On other occasions the initial contact is maintained. The proboscis next begins to move slowly over the body of the fish as the cone apparently attempts by touch to locate a soft area where injection of the radula tooth, which is held in the tip of the proboscis, is assured. With the exception of two instances, in all feeding sequences observed thus far in this study (a total of 20 observations on 4 individuals) the proboscis tip continued to pass over the body of the fish until it reached the ventral abdominal surface. Only when this area had been reached was the radula tooth injected and the proboscis contracted to pull the fish in toward the mouth (Plate 4, Figure 4). This aspect of the feeding sequence occurred with such rapidity it was impossible to separate individual events. Photographs at 1/250 second were blurred (Plate 4, Figure 4).

Of the two instances where injection of the radula tooth was not in the ventral abdominal area, one was an injection just ahead of the caudal fin into the lateral trunk musculature, while the other was, assumedly, into the soft tissue of the mouth of the fish. In this latter case,

the fish observed the moving tip of the proboscis and attacked it, probably as potential prey, taking the tip into the buccal cavity whereupon it was immediately stung. In both of these instances the fish were specimens of *Oligocottus snyderi*.

That the radula tooth is actually injected is certain for I have observed the actual tooth imbedded in a specimen of *Xerperes fucorum* at one end and held in the proboscis of the *Conus* at the other. The radula teeth are very large (6.8 to 7.6 mm in one specimen) and thus observable in large dissected specimens of *Conus purpurascens* without optical equipment.

On only one occasion did a fish escape after the injection of the tooth, despite the fact that injection of the tooth invariably caused violent thrashings by the fish. In this instance the fish (*Oligocottus snyderi*) swam straight to the surface of the water and sank immediately back to the bottom where it died in two minutes. It was then consumed by the cone.

When the captured fish has been brought up to the cone via contraction of longitudinal muscles of the proboscis, the muscular mouth surrounding the proboscis expands greatly and engulfs the fish (Plate 4, Figures 5 to 8). This process is usually completed within one minute. When the fish has been thus ingested, the cone begins to burrow into the sand.

Live fish do not seem mandatory for this species as on two occasions when dead *Oligocottus snyderi* were put into the aquarium they were attacked and eaten in exactly the same way as living fishes. However, both of the dead fishes used in these experiments were very fresh. It is not yet known at what time after death *Conus purpurascens* will refuse such fish. This is in contrast to KOHN's (1956) findings for *C. striatus*.

*Conus purpurascens* appears to be a nocturnal feeder as are most of the species of the genus (KOHN, 1959). In several instances, specimens having initiated attacks on fishes in a dimly illuminated room immediately ceased searching and retracted into their shells when bright light, especially daylight, was let into the room. Further study is being continued on this aspect of behavior.

### Explanation of Plate 4

Figure 1: *Conus purpurascens*, siphon out, and a specimen of the fish *Oligocottus snyderi* which has just been placed into the tank  
 Figure 2: *Conus purpurascens* with proboscis extended actively searching for the fish. The extended proboscis is visible below the fish  
 Figure 3: The proboscis of *Conus purpurascens* making initial contact with the fin of the *Oligocottus snyderi*

Figure 4: *Conus purpurascens* immediately after injection of the radula tooth into the *Oligocottus snyderi*. The blur is the thrashing fish

Figure 5: *Conus purpurascens* proboscis with impaled fish contracted, expanding its mouth to engulf the fish

Figure 6: *Conus purpurascens* beginning to engulf the captured fish

Figure 7: *Conus purpurascens* with fish almost completely engulfed by the expanded mouth and buccal cavity

Figure 8: *Conus purpurascens* with fish completely engulfed



Figure 1



Figure 2



Figure 3



Figure 4



Figure 5



Figure 6



Figure 7



Figure 8



Although it is not known with what frequency feeding occurs in nature in *Conus purpurascens*, under captive conditions specimens in my aquaria have fed on two days in succession indicating, as KOHN (1956, 1959) has reported, that digestion in this genus is extremely rapid.

*Conus purpurascens* also appears to be able to survive without food for periods of at least two months, the length of time specimens in the author's aquaria were held before feeding was initiated. This time interval of survival without food is similar to that reported for *C. californicus* by SAUNDERS & WOLFSON (1961). However, the author has maintained other tropical American *Conus* species alive in aquaria, notably *C. brunneus* Wood,

1828, and *C. virgatus* REEVE, 1849, for five months without feeding.

### SUMMARY

The feeding behavior of *Conus purpurascens* under captive conditions is described. *Conus purpurascens* was observed to attack and eat two species of fishes, *Oligocottus snyderi* and *Xerperes fucorum*. The feeding behavior was the same in all instances and was similar to that reported by KOHN (1956) for *C. striatus*. Feeding behavior in *C. purpurascens* appeared to be influenced by light.

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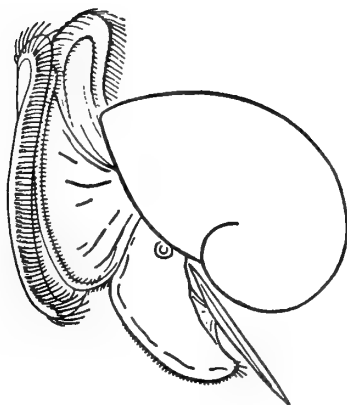
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## Note on the Radula of *Mitromica* BERRY, 1958

BY

JAMES H. McLEAN

Los Angeles County Museum of Natural History  
900 Exposition Boulevard, Los Angeles, California 90007

(1 Text figure)

THE SYSTEMATIC position of the monotypic species *Mitromica solitaria* (C. B. ADAMS, 1858) has long been a puzzle. Although the species has four columellar plaits with the heaviest fold in adapical position, it has other shell characters not typical of Mitridae: a thickened and highly denticulate outer lip, a suggestion of an anal sulcus, and sharply cancellate sculpture, characters stressed by BERRY (1958, p. 94) in his diagnosis of *Mitromica*. Copies of previously published illustrations of the holotype of *Mitromica solitaria* C. B. ADAMS and the synonymous *M. nodocancellata* STEARNS, 1890, are given by KEEN (1958, p. 428, text figure 646).

The radula in the Mitridae has been well documented and is considered a more reliable indicator of family and subfamily relationships than the shell (CERNOHORSKY, 1966). Examination of the radula of *Mitromica solitaria*, from a specimen collected at low tide, San Luis Gonzaga Bay, Gulf of California, skillfully mounted by Mr. Peter M. Oringer (Figure 1), shows the genus to belong to the subfamily Vexillinae of the family Mitridae. The rachidian tooth is bow-shaped and bears seven cusps, intermediate in character between that of the tricuspid rachidian of *Pusia* SWAINSON, 1840, and the multicusp-

radian of *Vexillum* RÖDING, 1798, figured by THIELE (1929, pp. 337-338, text figures) and CERNOHORSKY (1966, pp. 118-121, text figures). The lateral teeth are sickle-shaped as in both of these genera.

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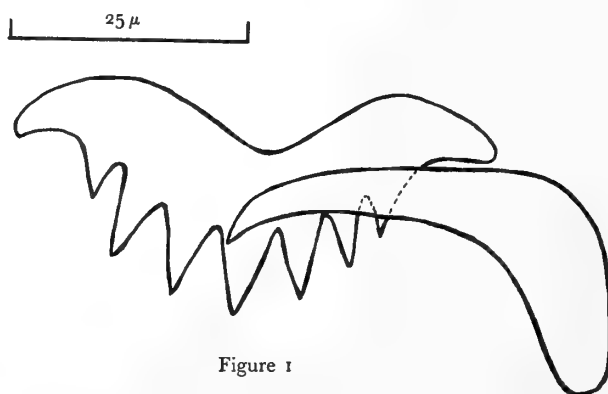


Figure 1

Radula of *Mitromica solitaria* (C. B. ADAMS).  
The rachidian plate and one lateral plate are shown

# The Shell Ornament of *Hysteroconcha* and *Hecuba* (Bivalvia): a Test Case for Inferential Functional Morphology

BY

ROBERT M. CARTER

Sedgwick Museum, Cambridge, England

(Plates 5 to 7; 2 Text figures)

FOR MANY YEARS zoologists have been making functional inferences about the animals that they study, and, in the case of vertebrate zoologists at least, this type of inference has often been made with a fair amount of scientific rigour. But the recent paper by GEIST (1966) on the evolution and functional significance of horn-like organs in the mammals convincingly demonstrates that even with such spectacularly developed and common organs as these there is still ample room for subjective interpretation and divergences of opinion. Unfortunately, the tendency in invertebrate studies has been for functional interpretations to be made merely as asides in the course of routine systematic work; at best such interpretations are generally loosely argued, at their worst they may even become self-contradictory. In the field of invertebrate palaeontology there has recently been a strong resurgence of interest in functional, as opposed to systematic, studies, and in a series of stimulating papers RUDWICK (1961, 1964a, 1964b) has outlined a rigorous 'paradigmatic' methodology which enables at least some degree of precision to be reached in such interpretations. Though the method was developed initially for fossil brachiopods, its applications are not restricted to any one group of animals, and its implications are equally broad.

## THE PARADIGMATIC METHOD

Briefly, the paradigmatic (or mechanistic) approach may be considered to consist of four logically discrete steps:

### 1. Perception

The animal structure in question is examined in some detail and compared with our knowledge of the biology of the animal's relatives, living and fossil, and with our knowledge of similar structures in unrelated animal groups. As a result of this comparison it is generally possible to

suggest more than one reasonably plausible function for the structure.

### 2. Specification

It is now necessary to test these various tentative functional interpretations against the different idealised structural specifications that are relevant to each. It is essential, in so doing, to take account of the limitations imposed by the properties of the materials involved (*e. g.* bone, muscle or calcium carbonate, etc.), where these factors are significant. One is thus led to the concept of establishing a **paradigm** for each postulated function. The paradigm is "the structure that would be capable of fulfilling the [postulated] function with the maximal efficiency attainable under the limitations imposed by the nature of the materials" (RUDWICK, 1964a, p. 36).

### 3. Evaluation

By comparing the observed structure with its paradigm for each postulated function it is possible to get some idea of the degree of efficiency with which the observed structure could have fulfilled each function. As RUDWICK (1964a, pp. 36-37) has already stressed, it is most important to note that closeness of approximation of a structure to a given paradigm **only** measures the degree of possible functional efficiency of the structure for that paradigm; it tells us nothing directly about the probability that the function we are considering is in fact the correct function.

### 4. Interpretation

Thus far the analysis has been entirely methodological, and therefore relatively objective. However, to choose between several competing paradigmatic analyses inevitably involves a higher degree of subjectivity. It is necessary at this point to digress slightly.

Most animals that have been adequately studied demonstrate a high level of integration between function and structure. Indeed, it was presumably just this that gave rise to the presently popular technique of viewing animals as functional units of the same type as machines. But it has become accepted that in writing of animals in this way the worst crime is to use language that might be construed as teleological in any sense. PITTENDRIGH (1958, p. 394) has pointed out that an animal, just like a machine, is an end-directed mechanism, and that the slightly hysterical attempts of many writers to use non-teleological language are based "on the mistaken view that the efficiency of final causes is necessarily implied by the simple description of an end-directed mechanism" (*l. c.*, p. 393). PITTENDRIGH further maintains that it is wrong to consider, as many of us do, the animal as a system some features of which may, or may not, be adaptive: "the living system," he writes, "is all adaptation insofar as it is organized." In addition, he takes issue with HUXLEY for having called the organism "a bundle of adaptations" because such a statement implies that organisation is an additive phenomenon, and that discrete adaptations can be isolated from the system.

It would seem to be a dangerous procedure, then, to abstract one particular structural feature of an animal, and to attempt to analyse its probable adaptive or functional role, for "the organism's ends" are likely to be often "served in complex ways unamenable to simple description." But presumably PITTENDRIGH would be the first to agree that it is only by initially, and tentatively, treating the organism as a bundle of adaptations, and by attempting to analyse each of these adaptations separately that we are in the end able to piece them all together and approach the task of interpreting the animal as "all adaptation."

Some structures approach their paradigm very closely – for example, the camouflage of many moths and stick insects, if not corresponding 100% with a camouflage paradigm, is certainly very close to it – but it should be obvious that no structure will ever perfectly fulfill its paradigm, for no animal functions at 100% efficiency. Further, in line with the points quoted above, since all structures are an integrated part of the adaptation of the whole organism they are very rarely, if ever, going to be the result of a single steady selective pressure. Commonly we might expect a structure to be selected for more than one specific function and hence to approach several paradigms loosely, and none specifically. Indeed, RUDWICK (1965) has already described a structure (spines on the Jurassic brachiopod *Acanthothiris*) that he considers to have probably served two discrete functions; and

GEIST (1966, p. 192), in writing of the functions of horn-like organs in vertebrates, concludes that "cervid antlers and bovid horns evolved convergently and function as weapons, secondly as guards and thirdly as organs binding opponents together during pushing and wrestling contests."

Assuming, then, that a structure will never completely fulfill its paradigm, in a given instance we are faced with making comparisons between the actual structure, and the structural paradigms of several possible functions. We adopt for this the procedure outlined by RUDWICK (1961) in his introduction of this methodology: whichever paradigm, of several alternatives, is adjudged to be **most closely** approached by the structure in question, that paradigm is **most likely** to be the paradigm of the sole correct function, or of the dominant function of several. The other postulated functions may then (subjectively) be considered as close enough to their paradigms to be interpreted as secondary functions, or alternatively, they may be discarded.

It is important to note that it is at this interpretative stage that a paradigmatic analysis reaches its least rigorous point, for there is generally no quantitative way of measuring how closely a structure approaches several alternative paradigms. Hence the choice between such paradigms is certainly subjective, and must depend largely on the preferences and opinions of the writer concerned.

## THE QUESTION OF FUNCTIONALITY

The question as to whether all structures **must** of necessity have a function is, of itself, outside of paradigmatic methodology. But it is a question that cannot be evaded when interpreting animal structures, for the possibility must always be considered that a given structure is in fact non-functional (*i. e.* non-adaptive). "The living system is all adaptation insofar as it is organized": PITTENDRIGH would thus presumably maintain that all major structures are adaptive, and hence have a function. RUDWICK (1964a) is primarily concerned with the logical impossibility of proving non-functionality, but he clearly makes the point (pp. 35, 38) that, without prejudice to the correctness or not of a general principle of functionality, unless we initially assume that a given structure is functional "we shall fail even to perceive the evidence on which any functional reconstruction must be based."

However, these two writers' views apart, it is clearly impossible to assert that all structures **must** be functional, except in a semantically very loose sense, for there are at least two obvious types of morphological structure for which such an assertion would be false:

## 1. Pleiotropic genetic effects

The pleiotropic effect, whereby one gene locus may give rise to manifold morphological consequences, has long been known. Predictably, most of the cited examples involve *Drosophila*; for instance, the mutation 'vestigial' in *Drosophila* acts primarily to reduce the wing size, but it also makes certain bristles erect instead of horizontal, modifies the balancers, and has noticeable effects on the wing muscles, the shape of the spermatheca, the speed of growth, life length and fecundity of the insect (DOBZHANSKY, 1941). There is no doubt that pleiotropism is a widespread genetic phenomenon affecting all groups of animals. Human ingenuity is such that, if pushed to it, a discrete function could readily be invented for all the above morphological changes; or, to put it another way, a different selective advantage could be attributed to each of them. But a paradigmatic analysis of any one of these morphological effects would almost certainly be trivial, for they all form part of a stable genotype and cannot meaningfully be treated in isolation. That is not to say that they are not all individually subject to natural selection, for modern evolutionary theory holds that selectively neutral characters are very rare. Rather, it seems probable that, though all the characters of a pleiotropic set may be subject to individual selection, in most cases the selection for the (or for a) dominant character swamps the effects of the others.

The genetic research necessary for recognizing pleiotropism has scarcely been started for many groups of Recent animals, and it is all but impossible that we shall ever be in a position to describe the genome of fossil forms. Hence the most reasonable approach to this problem is presumably to treat well developed structures (such as, say, elephant tusks, or the spines described later in this paper) as truly adaptive, and assume that they are not merely 'side-effects' due to pleiotropism. In the present state of knowledge there appears to be no rigorous way of justifying such decisions; and only experience, or intuition, can help us make them correctly.

## 2. Vestigial structures

A further example of a non-functional structure is one that is adjudged to have become obsolescent after a fairly long phyletic history. Such vestigial structures are inferred to have been functional, and hence selected for at some former time, though at the present time they appear to have no continuing usefulness.

The paradigmatic interpretation of vestigial structures is also difficult, for they are capable of closely approaching the paradigm of their ancestral function; as examples one might quote the unerupted teeth of the baleen whales,

or the rudimentary limbs of some snakes. However, the problem is not as difficult as with pleiotropism, for vestigiality usually leaves some morphological trace – in the case of a fossilised baleen whale jawbone one would certainly be suspicious of the apparent lack of wear on the teeth. Nevertheless, one has no case for insisting *a priori* that all vestigial structures are always going to be recognisable as such because of their inevitably possessing certain inconsistencies in their morphology; and this is particularly true of fossil animals where only part of the total morphology is preserved. The possibility of vestigiality, then, must always be borne in mind in functional studies.

## PHENOTYPIC RESPONSES

The classic types of phenotypic response to the environment, such as an oyster moulding itself to the substrate or the shells of a particular species of mollusc being thinner in sub-saline water, either have an obvious function, or do not require functional interpretation. But GILBERT (1966) has recently described a fascinating and unusual type of phenotypic morphology in the rotifer *Brachionus calyciflorus* PALLAS, 1766. This species normally possesses two pairs of short anterior spines, and a further pair located posteriorly. If *B. calyciflorus* is kept in cultures of the carnivorous rotifer *Asplanchna brightwelli* HUDSON, 1889, its female parthenogenetic offspring have an additional pair of long posterolateral spines – structures that were completely lacking in the previous generation – and there is also an induced relative elongation of the normal spines. Eggs from mothers grown in the conditioned medium that are transferred to fresh medium immediately after extrusion develop into long spined forms; conversely, eggs from mothers grown in fresh medium and transferred on extrusion to conditioned medium hatch into short spined forms. Successive offspring from the same mother exhibit decreasing spine production. As GILBERT concludes: "the production . . . of extra spines was mediated by a factor released into the medium by *Asplanchna*, and represents a phenotypic response of undoubted adaptive significance" – long spined *Brachionus* being far more difficult for *Asplanchna* to eat.

It is presumably a moot point whether this rather straightforward type of phenotypic response can be expected in animals higher than rotifers, but it is as well to be aware of the existence of such a phenomenon, even if it should presently appear to be confined to one of the lower animal groups. It would seem likely that such a confinement reflects our lack of knowledge of the phenomenon in other phyla, rather than its true absence.

Since a paradigmatic analysis is not concerned with how a particular structure arose, but only with how well adapted it is, phenotypic structures are perfectly amenable to paradigmatic interpretation. However, should it transpire that the phenomenon described above be widespread in different animal groups, there might be a case for some amendment of the present methodology.

## SUMMARY

Though it is not possible to maintain the rigour of paradigmatic methodology right through the functional interpretation of animal structures, such a methodology is an essential tool in any closely reasoned functional analysis.

The palaeontologist normally accepts as part of his discipline an almost complete ignorance of the soft-part anatomy and the behaviour patterns of the specific fossils that he studies. Of course, he may make much use of the current biological knowledge of extant relatives of the animal in question, but in many cases such knowledge is appallingly scanty. As with most types of scientific method, the paradigmatic is dependent for its success on its initial data – these need to be both sufficient and of good quality. Palaeontological data are always relatively insufficient in that soft parts are rarely fossilised.

Theoretically the neontologist is in a much stronger position, for he should have a comprehensive knowledge of the anatomy, ecology and ethology of the animal he is studying. But in fact, so little work has been done on many groups of Recent animals, apart from routine systematics, that the neontologist is in almost exactly the same position as the palaeontologist. This is especially so in invertebrate groups, and particularly true of the Mollusca.

*Hecuba* and *Hysteroconcha* are two groups of living bivalves about which very little has been published outside of taxonomic information (and even that is scarce). The degree of interest shown in such spectacular shells by early European shell collectors is reflected by the voluminous

description of *Hysteroconcha* in *Systema Naturae* – in the entire 'Regnum Animale' only *Homo sapiens* and *Apis mellifera* (the honey bee) can record a longer entry (DODGE, 1952, p. 87). The demand for specimens of these shells was due mainly to their beauty of form, but their exotic origins and relative scarcity were contributing factors; and even today it is not easy to come by specimens with wholly intact spines. Inevitably, therefore, attention has centred on the aesthetic appeal these shells made, rather than on their scientific significance. It has passed unnoticed that *Hysteroconcha*, known from the tropical Americas to the Northern Americas, and *Hecuba*, known from the western Indo-Pacific, have independently acquired the remarkably similar morphological structures that constitute their main attraction from the collectors' point of view.

The unfortunate lack of published data on these shells carries one unexpected advantage – it enables a 'palaeontological type' of paradigmatic analysis to be carried out with which future observations on the living animal may be compared. Thus this paper may serve as a partial 'test case' of paradigmatic methodology; the amount of light thrown on the functional suggestions made herein by future research on the living animals will be some guide as to the reliability of the methodology, and perhaps tell palaeontologists just how far it is possible to make reasoned inferences from the incomplete data of dead shells.

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## *Hysteroconcha*

In most respects *Hysteroconcha* is a typical member of the Pitarinae (Plate 5, Figure 1), possessing the characteristic dentition, moderately deep pallial sinus and concentric ornament of that group. It differs, however, in the possession of two remarkable sets of spines, one (the

## Explanation of Plate 5

Figure 1: *Pitar (Hysteroconcha) lupanaria* (LESSON, 1830), x 2; Recent, America; Saul Collection, Zoology Department, University of Cambridge. The left valve of a pair; note especially the rounded concentric ridges, raised at the anterior end of the shell.

Figure 2: *Pitar (Hysteroconcha) dione* (LINNAEUS, 1758), x 2; Recent, America; Sedgwick Museum Recent Mollusca Collection, Cambridge University. In this, and the specimens figured as 3 and 5, note the characteristic position and morphology of the muricid gastropod boring.

Figure 3: *P. (H.) dione* (LINNAEUS), x 2; Recent, America; Saul Collection.

Figures 4 to 7: *P. (H.) lupanaria* (LESSON), x 2; Recent, America; Saul Collection. A beautifully preserved double-valved specimen, photographed from varying angles to show the arrangements of the spines. Note particularly that no protection is afforded by the spines to guard the posterior gape against turbid sediment.

[The magnification is stated approximately for all figures]

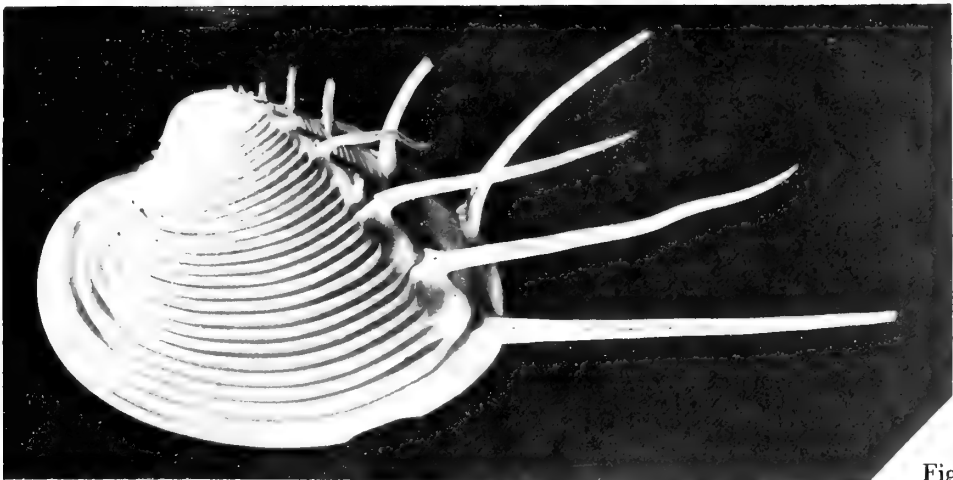


Figure 1



Figure 2



Figure 3

Figure 4

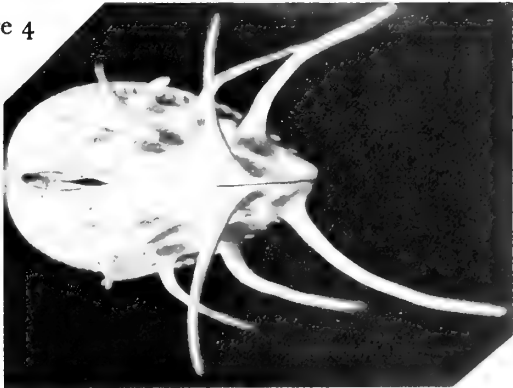


Figure 5

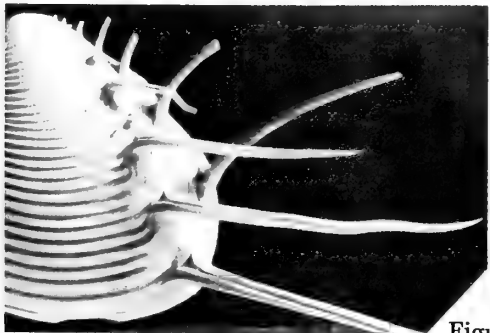
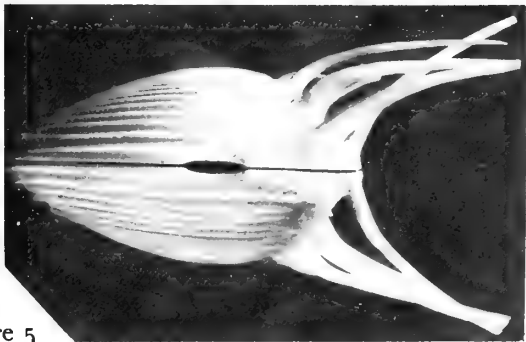


Figure 6

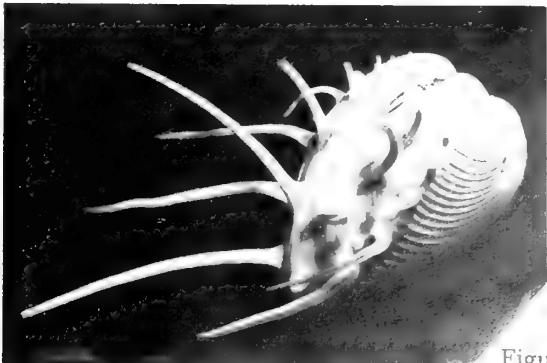


Figure 7



primary row) carried on the rounded posterior carina delimiting the edge of the corcelet<sup>1</sup>, and the other (the secondary row) along the shell sector marking the edge of the escutcheon.

## ECOLOGY

*Hysteroconcha* is collected living on sandy beaches, and also offshore to depths of about 13 fathoms (KEEN, 1958). Mr. J. Q. Burch (personal communication) has collected it living on sandy beaches near Guaymas, Sonora, Mexico. He comments that it is common as an intertidal form when a living ground has been located (*i. e.* there are large numbers of individuals), but that localities where it occurs are rare. Like many intertidal bivalves it remains buried under the sand when the tide is out, rising to the substrate surface to feed on the incoming tide. Its feeding position I thus infer to be with the posterior spines, and probably most of the corcelet, protruding above the substrate. The anterior end of the shell is undoubtedly always buried.

The only predator reported as actually feeding in the field on *Hysteroconcha* is *Polinices reclusianus* (DES-HAYES, 1839), which lives under the sand in the same habitat (Mr. Burch, personal communication). Other predators that are found in the same type of ecological station include muricid gastropods (*Forreria*, *Hexaplex*, *Muricanthus*), *Natica*, *Oliva*, asteroids (*Astropecten*), crabs and fish (Dr. M. Keen, Professor F. M. Bayer, personal communication).

## DETAILED MORPHOLOGY

### *Hysteroconcha lupanaria* group

[*Hysteroconcha lupanaria* (LESSON, 1830)]

This species group can be recognised by the large size of the adult shell (up to 60 mm long, excluding spines), the possession of a large pre-spinous dissoconch (about 6 mm long) and the characteristic rounded concentric ornament (not sharp, raised lamellae) in the centre of the main disc.

The exact pattern of spine secretion is variable within all species of *Hysteroconcha*. However, an attempt is made below to describe the pattern that sets of spines on the majority of animals approximate to; it must be stressed that this involves considerable generalisation, and that

it will be possible to find an animal for which just about every statement made below is mildly incorrect.

### Spines

On any one valve the first spine secreted in ontogeny is generally of the primary row, and thereafter spines are secreted at regular intervals alternately on the primary and secondary spine rows. On a particular spine row, say the primary, though the spines are definitely secreted on a regular pattern, the distance between any two consecutive spines increases during life, *i. e.* the ontogenetically earlier spines are closer together than the later adult ones.

The pattern of spine arrangement between the two valves is also variable, but generally the spines of the two primary rows are secreted alternately, whilst those of the two secondary rows are introduced in symmetrical pairs at the growing edge (Plate 5, Figures 4, 5, 7). However, not uncommonly the spines of primary and secondary rows are both introduced as symmetrical pairs at the growing edge. Irrespective of this, the alternating relationship between spines on the primary and secondary rows of one valve is generally maintained (Plate 6, Figure 8).

The spines of the primary row rise from the valve edge at a fairly high angle in an almost truly radial direction (Plate 5, Figures 5, 6). However, they quickly become directed posteriorly, at the same time bending markedly into subparallelism with the plane of the commissure. They may achieve a length the same as, or a little longer than, the shell length at the time of their inception (*e. g.* spine length 34 mm, shell length 27 mm).

The spines of the secondary row rise from the shell edge at a very high angle (over 80°), and are slightly directed posteriorly from a true radial direction (Plate 5, Figures 4, 7; Plate 6, Figure 8). They also bend inwards toward the plane of the commissure, but much less slowly than do the spines of the primary row. As a consequence, at about half their normal length they meet with, and pass through, the plane containing the spines of the primary row (Plate 5, Figure 5). The length of the secondary row spines is normally less than the fully developed spines of approximately the same growth stage on the primary row, but they may grow to as much as  $\frac{2}{3}$  of the length of the shell.

The spines themselves (that is, apart from their length and orientation relative to the valve surface) are of identical morphology in both primary and secondary spine rows. They are rounded and smoothed on the commissural side, and reflected at the edges so that a marked groove or channel runs the length of the upper surface of the spine (Plate 6, Figures 8, 10). The upper surface of the spine carries typical shell surface growth striae; they taper gradually to an extremely acute point. Even in the juvenile they are relatively thick at the base, and hence strong,

<sup>1</sup> The term "corcelet" is used in this paper for a morphologically differentiated area lying outside the escutcheon at the posterior end of the shell. A further discussion of the term may be found in CARTER, 1967.

for the size of the shell (*e.g.* Plate 5, Figure 5). For instance in a shell 30 mm long, the last secreted primary spines are 2.1 mm thick at the base, tapering to a fine point over a spine length of 33 mm. In the largest adults that I have seen the spines are generally relatively shorter than this, but obviously extremely strong. For example in a specimen 50 mm long, the latest formed spines are only 24 mm long, but are 3 mm thick at the base: they therefore taper relatively rapidly.

### Concentric lamellae

These are only developed at the anterior end of the shell in the form of flaring, recurved, sharp concentric rings, sometimes as much as 3 mm high. As they are traced across the main disc they grade insensibly into low, irregular, rounded concentric rings; in mature specimens they may become completely obsolescent just anterior to the posterior carina.

### *Hysteroconcha dione* group

[*Hysteroconcha dione* (LINNAEUS, 1758)]

This species group can be recognised by the small pre-spinous dissoconch (about 3 mm long), the correspondingly smaller size of the adult shell (commonly less than 50 mm long), and the possession of sharp raised concentric lamellae over the whole of the main disc, and not just confined to the anterior end.

### Spines

The morphology of the individual spines is much the same as in *Hysteroconcha lupanaria*, but the following minor differences in arrangement and morphology appear to be relatively consistent.

1. On any one valve the first spines secreted in ontogeny are generally coincident in the primary and secondary spine rows.

2. The spines are relatively more numerous (compare Plate 5, Figures 2 and 5); there are therefore fewer concentric laminae between each consecutive pair of primary row spines.

3. The spines are relatively shorter (for example, primary spine 14 mm long in a 28 mm long shell), broader at the base (as much as 4.5 mm wide in a 34 mm long shell), and more markedly flattened than in *H. lupanaria* (Plate 6, Figure 9).

4. Each spine is very clearly a continuation of a concentric growth element.

5. There is a tendency for the secondary spine row to have alternating introduction of spines on the two valves, and for the primary row to have paired spines (Plate 6, Figure 9).

A morphological detail especially marked in *Hysteroconcha dione*, but also present in *H. lupanaria*, is the cessation of the secondary spine row at a particular growth stage (Plate 6, Figure 9). This is generally when the shell has reached a length of about 20 to 30 mm. In some specimens an initial cessation at this shell size may be followed by a final pair of secondary row spines being secreted after a considerable gap. For instance, in one specimen the initial cessation came at about 20 mm, but there is another well developed pair of spines secreted at a shell length of 38 mm.

### Concentric lamellae

The whole of the main disc between the carina carrying the primary spine row and the lunule is ornamented with spaced raised concentric lamellae, often slightly recurved dorsally. Each lamina is about 0.6 mm thick and perhaps 2 mm high; the anterior end of a lamella is markedly flared, and the distance between the shell surface and the lamina top may then be over 3 mm (Plate 5, Figure 1). The pre-spinous dissoconch does not have

## Explanation of Plate 6

Figure 8: *Pitar (Hysteroconcha) lupanaria* (LESSON),  $\times 3\frac{1}{2}$ . Same specimen as figures 4 to 7. An enlarged view of the primary spine row; note the comparative regularity of spine secretion with respect to the concentric ornament; generally any two spines are separated by 3 to 4 concentric ridges.

Figure 9: *P. (H.) dione* (LINNAEUS),  $\times 3$ ; Recent, America; Saul Collection. The primary (outer in this view) spine row delimits the edge of the corcelet; inside this are two further differentiated areas, conveniently termed the inner and outer escutcheon as both correspond to the growth tracks of particular parts of the dentition.

Figure 10: *P. (H.) lupanaria* (LESSON),  $\times 4$ . Same specimen as fig.

[The magnification is stated approximately for all figures]

8. Note the 'umbra' zone dorsal to each primary row spine. This zone carries growth lines clearly displaying that an epithelial tongue continued to secrete the spine after it had become displaced dorsally from the growing edge of the shell.

Figure 11: *Hecuba scortum* (LINNAEUS, 1758),  $\times 5$ ; Recent, Indo-Pacific; Saul Collection. View of the frills from a dorsal aspect showing the shallow, though marked, radial gutters, and their correspondence with the radial ornament.

Figure 12: *Hecuba scortum* (LINNAEUS),  $\times 3$ . Same specimen as figure 11. View of the frills from ventral aspect. Note the structural frill ribs – each of which corresponds to a radial gutter on the dorsal surface of the frill (*cf.* fig. 11).



Figure 8

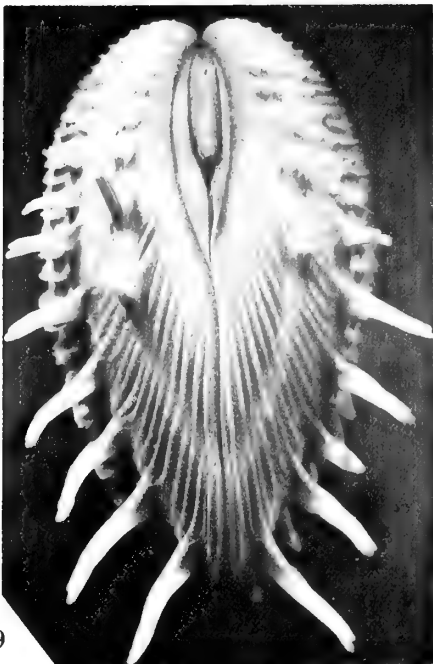


Figure 9

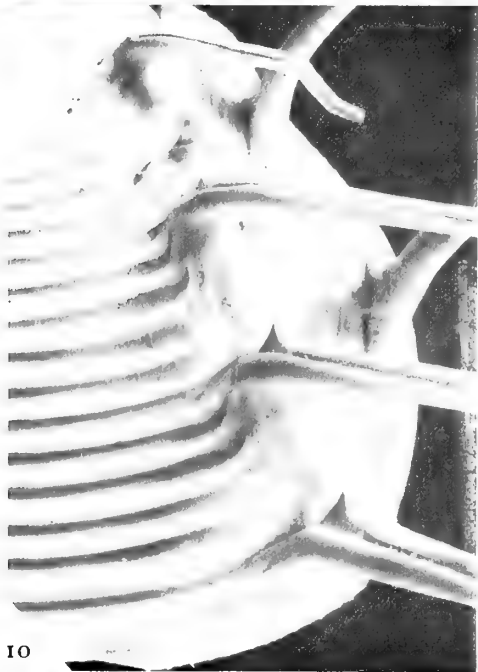


Figure 10



Figure 11

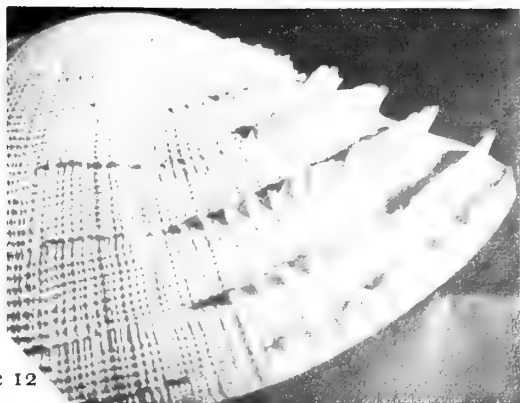


Figure 12



raised lamellae, though it does have low rounded concentric ornament. There may also be faint concentric ornament on the corcelet and escutcheon (Plate 6, Figure 8).

### SHELL STRUCTURE

Macroscopically a section through the shell reveals the characteristic three shell layers, each clearly marked by its differing texture (Text figure 1). The ectostracum is

stracum. They are clearly due to a periodic extension of the mantle beyond its normal shell edge limits, but secretion continues unchanged during these periods of mantle extension.

The boundary between the ectostracum and the mesostracum is gradational; there is a gradual fading away of the crossed lamellae into the mesostracum. The mesostracum itself is composed of thin subparallel laminae and carries many conspicuous secretion traces; it is otherwise microscopically structureless.

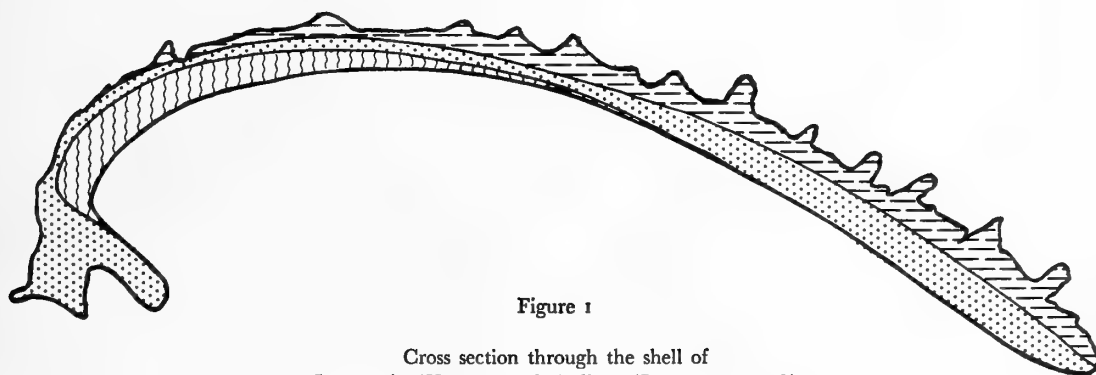


Figure 1

Cross section through the shell of  
*Lupanaria (Hysteroconcha) dione* (LINNAEUS, 1758)  
The three shell layers correspond to the endo-, meso- and ectostracum respectively.  $\times 6$ .

white, with pink tinges near the shell surface, and clearly composed of crossed-lamellae of calcite. The mesostracum is structureless but has a very characteristic grey 'greasy' appearance like that of nepheline. The endostracum is a light grey-white, and coarsely layered.

Microscopically (Text figure 2) the ectostracum is made up of fairly coarse crossed lamellae – a large lamella being about 0.05 mm wide at its thickest point – which are always at right angles to secretion traces, and thus clearly reflect the actual direction of shell secretion. Bundles of crossed lamellae are terminated ventrally by strong secretion traces; these presumably represent growth pauses of greater or lesser extent. The individual calcite folia can often be traced across these secretion traces, but the fact that this is not always so – sometimes there is a completely new and unrelated set of folia initiated on the ventral side of the trace – lends credence to the suggestion that the traces represent extended growth pauses. The individual folia are noticeably finer on the inner side of the ectostracum.

The raised concentric ridges on the shell surface, and therefore the spines, are entirely built of ectostracal shell material that is identical with that of the main ecto-

The endostracum coincides with the area of shell inside the pallial line, and abuts sharply behind the dentition (Text figure 1). It is microscopically very similar to the mesostracum, but it is clearly separated from that layer by the thin pallial myostracum. There do not appear to be any shell canals [*sensu* OMORI & KOBAYASHI, 1963; tubule (OBERLING, 1964) is already in use for a part of the stomach diverticula].

### INFERRED PATTERN OF SHELL SECRETION

There is a certain rhythmical activity in the mantle edge of *Hysteroconcha*, similar to that in many less striking venerids, which results in the secretion of concentric shell ornament. The activity takes the form of the extension of a narrow strip of mantle beyond the general shell edge, and its reflexion to make an angle of about 60° with the plane of the commissure. Whilst in this relatively exposed position outside the shell, the mantle secretes a layer of shell about 0.6 mm thick. Generally the extended mantle strip stretches from the edge of the lunule to the primary spine row and thus the result is raised concentric lamellae of similar disposition.

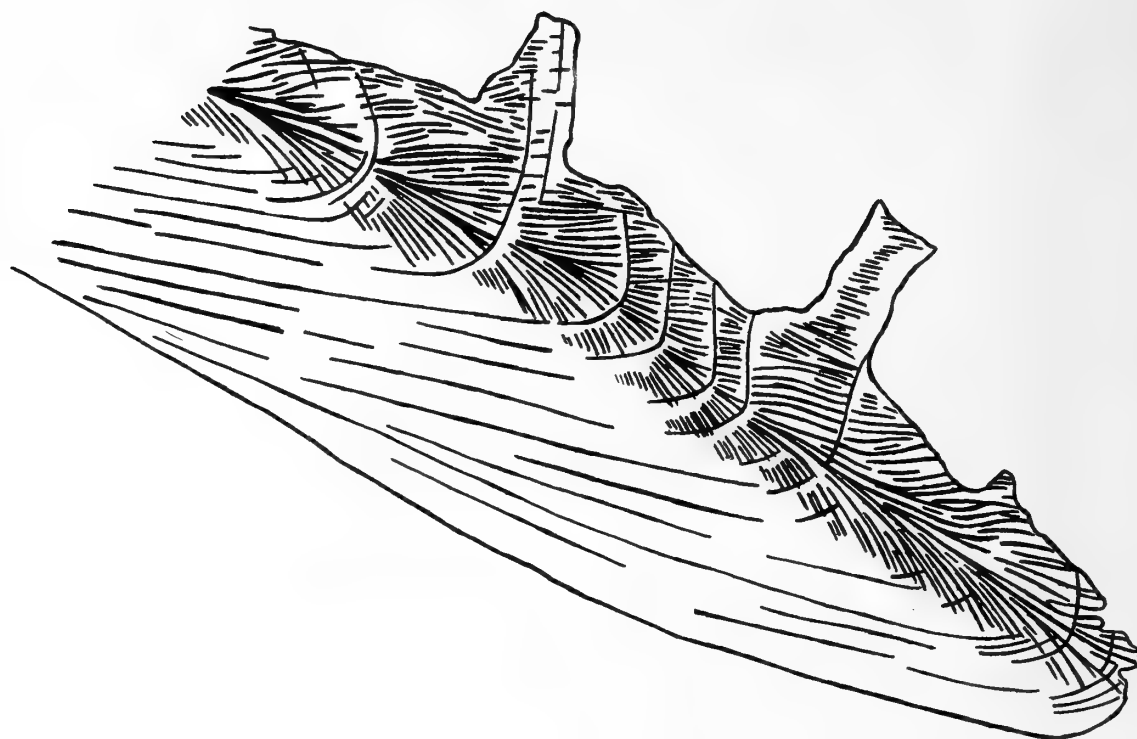


Figure 2

Enlarged view of the valve edge ( $\times 30$ ) showing only meso- and ectostracum. Note the gradational boundary between the two layers, the fact that the concentric lamellae are constructed entirely of ectostracum, and the fact that the crossed calcite lamellae of the ectostracum record the actual direction of shell secretion at any point.

Upon this basic pattern is superimposed another: about every third mantle expansion a small tongue of mantle at the posterior end of the raised mantle strip starts to expand locally, secreting as it does so. This local expansion is presumably caused by localised mantle cell generation. The result is the gradual building of

a projecting spine of calcareous material, smooth underneath (analogous to the normal internal shell surface), but bearing above the typical growth lines and micro-ornament of the external shell surface. The tongue of mantle continues to expand, all the time secreting and closely adhering to the spine that is resulting. The edges

### Explanation of Plate 7

Figure 13: *Hecuba scortum* (LINNAEUS),  $\times 2$ ; Recent, Indo-Pacific; Saul Collection. Right valve of a pair, showing the general morphology, and an unsuccessful gastropod boring.

Figure 14: *H. scortum* (LINNAEUS),  $\times 8$ ; Recent, Indo-Pacific; Saul Collection. Enlarged photograph of the posterior spine row; note the pointed nature of the spines and the presence of a dorsal keel.

Figure 15: *H. scortum* (LINNAEUS),  $\times 4$ . Same specimen as figure 14. Muricid predation localised on the mid-ventral border (cf. figs. 2, 3 and 5).

Figure 16: *Spondylus* spec.,  $\times 3$ ; Recent, unlocated; McAndrew Collection, Zoology Department, University of Cambridge. Photograph of the under side (i. e. the side facing the opposing valve) of a major spine. All the spines on this specimen have expanded tips that one might suggest as paradigmatic for sensory mantle protection (N. B. This is only taken as a convenient example; I am in no way implying that the spine figured should be so interpreted).

Figure 17: *H. scortum* (LINNAEUS),  $\times 3$ . Same specimen as figure 15. General view of the corcelet, and spine bearing posterior ridges.

[The magnification is stated approximately for all figures]

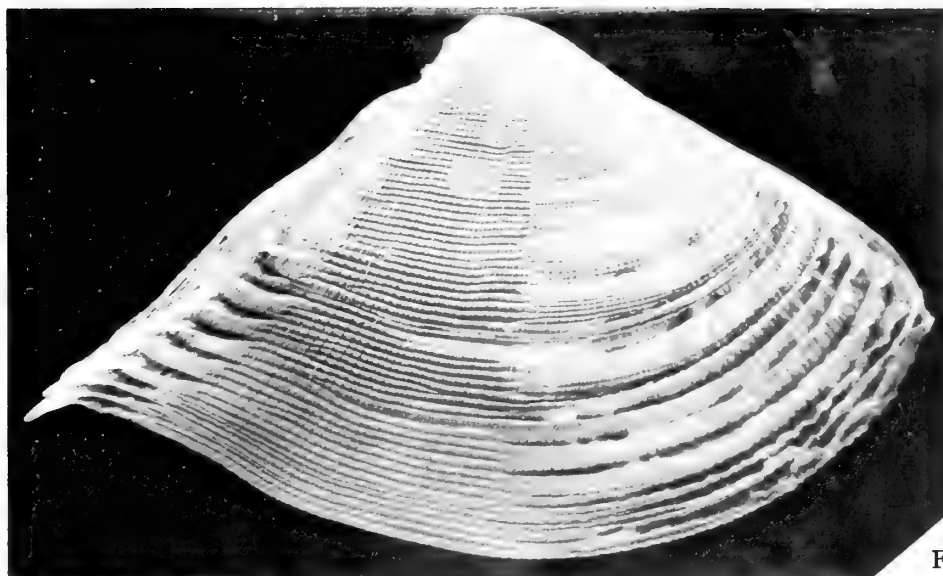


Figure 13



Figure 14

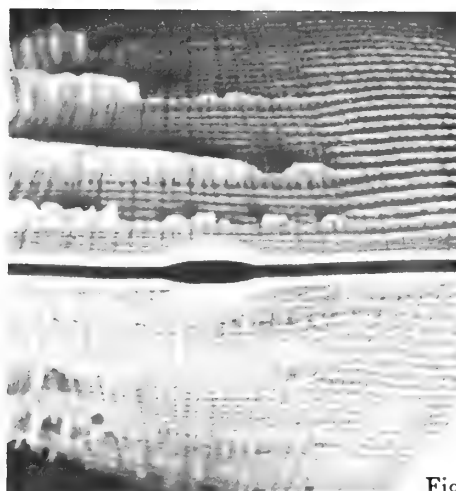


Figure 15



Figure 16

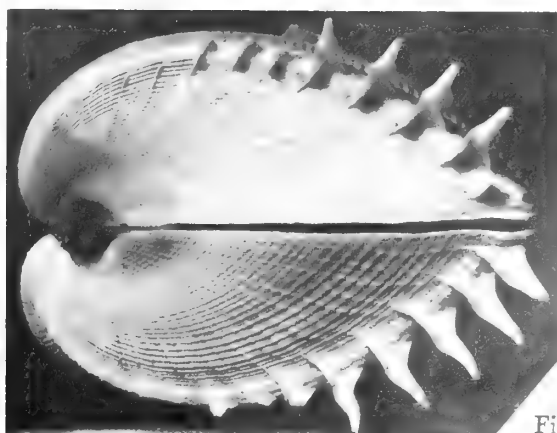


Figure 17



of the mantle tongue curl upwards somewhat resulting in reflexed smooth edges to the spine (Plate 6, Figure 8). In specimens of *Hysteroconcha lupanaria* these reflexed edges may meet above the spine thus completely obliterating any sign of the upper ornamented surface of the spine. Before the spine has reached its full length the continued general secretion of the whole mantle edge has resulted in further growth of the shell all round the commissure. Hence the base of the spine becomes relatively distant from the shell edge, but it continues to be lined with epithelial material and to grow in length as is shown by the marked 'umbra' zone immediately ventral to the spine; this umbra zone is shown by a marked re-entrant in the growth lines (Plate 6, Figure 10).

When the growth of the spine is completed it would seem likely that the mantle tongue responsible atrophies. Irregularities in the concentric growth ornament on the main disc can often be correlated with the continued growth of spines that are no longer right on the valve edge.

## FUNCTIONAL INTERPRETATION

### Spines

The following functions are considered:

1. The spines might serve as devices for stabilizing the shell in a shifting substrate.
2. The spines may bear some relationship to the feeding mechanism or water circulation system of the animal; this would correlate with their location precisely at the boundary of the siphonal area.
3. The spines might be interpreted as protective cover, or support, for sensory mantle outposts giving relatively early warning of the presence of predators, or silt-laden water. That the spines themselves are sensory is a possibility that must also be considered.
4. The spines might be interpreted as structural defensive mechanisms combating predation.

### Rejected Interpretations

In view of the fact that the spines are not buried when the animal is in its normal feeding position, the first suggestion seems unlikely to be true. However, even if the shell were totally buried, the spines would act as relatively inefficient stabilising devices. Effective stabilisers, by virtue of their working principles, must be broad and flat, and have a large surface area oriented at right angles to the direction of expected movement. The long pointed spines of *Hysteroconcha* do not remotely approach this paradigm. One might make the stabiliser function more plausible by suggesting that the spines, since as a set they are oriented more or less parallel to the substrate,

prevent the animal from sinking into the substrate, *i. e.* that they act as a type of "snowshoe." But again the same objection may be made: the spines should paradigmatically be flattened structures lying along the surface of the substrate; in fact they are pointed and project at right angles to the surface of the substrate.

In order to have an advantageous effect on either feeding or water circulation systems, the spines would need to act as a set to form either a grill or a mesh for preventing the entry of harmful particles into the inhalent siphon (*cf.* RUDWICK, 1961). But this hypothesis is precluded by the fact that the spines are oriented in such a way as to conspicuously offer no grill or mesh protection whatsoever to the siphons or siphonal gape (Plate 5, Figure 4).

Dealing now with the third postulate: undoubtedly the mantle tissue lining the spines retains certain of the sensory abilities that the normal mantle edge possesses. However, if the main object of the exercise is to achieve a piece of sensory mantle edge as distal as possible from the commissure edge (the spine then being inevitably secreted, and serving only as a protective cover for the contained tissue), one would expect to find that the mantle outpost comprised at least the two outer folds of the mantle edge: the outer fold in order to have secreted the spine, and the middle fold in order to provide a sensory outpost. Though I have not been able to procure a preserved animal of *Hysteroconcha*, by analogy with the spines of *Spondylus* (which carry only outer mantle fold epithelia to their tip) it seems unlikely that a sensory mantle outpost was the reason for the spines on *Hysteroconcha*. An additional factor bearing against this hypothesis is that a spine which functions as a protective sheath for an early warning mantle should paradigmatically be broad (commensurate with its not interfering with normal feeding currents), convex downwards, and might be expected to carry some sort of an expanded tip in order to provide for as large an area of sensory mantle as possible at a distance from the shell edge (*cf.* Plate 7, Figure 16). The spines of *Hysteroconcha* are narrow, concave downwards, and extremely sharply pointed.

However, though I think it unlikely that the primary function of the spines is as protection for the exposed mantle tissue that secretes them, it is an inevitable consequence of all spine morphology that the spines themselves serve at least partly as sensory structures. Undoubtedly the contact of any browsing predator with the distal end of the spines would result in the immediate closure of the shell, and hence they do provide a relatively 'early warning' of potential danger. Yet one would anticipate that if this had been their primary function, the selection pressure responsible for their perfection would have fa-

voured individuals with spines like that of Plate 7, Figure 16 – for such a spine is itself every bit as effective as the pointed spines of *Hysteroconcha* for serving as a sensory structure, and carries the additional advantage of acting as an efficient protection for the mantle tissue (sensory or secretory) that lies beneath it.

#### Spines as a Protective Structure

The most promising of the initially postulated functions is that the spines serve for the protection of the animal.

To be effective as a defence structure spines would be expected to a) guard the most vulnerable part of the animal; b) be as long as possible commensurate with their being sufficiently strong; c) taper to a sharp point; and d) be so oriented as to face the direction of approach of expected predators. The spines of *Hysteroconcha* approach very closely to such a structural paradigm.

On a *a priori* grounds one would expect small sized predators to experience more difficulty when preying on *Hysteroconcha* than when preying on a similar shell without the posterior spines. There are two reasons for this: firstly, the spines increase the effective size of the shell and hence help to prevent the wholesale ingestion of the shell by predators whose mouth size dictates the size of food that they eat (small fish, intraorally digesting asteroids); secondly, the effect of a closely spaced set of sharp spines must have a strong deterrent value against those predators that actually have to open the shell before eating its contents (extraorally digesting asteroids, gastropods, perhaps Crustacea). Such aquarium observations as I have been able to make confirm these *a priori* postulates; both *Asterias rubens* (LINNAEUS, 1758) and *Buccinum undatum* (LINNAEUS, 1758) seem to (subjectively) experience more difficulty in attacking baited model shells that possess spines than they do in attacking similar shells but without spines.

From the experiments of CHRISTENSEN (1957) it has become obvious that virtually nothing will protect a bivalve from predation by a determined asteroid. CHRISTENSEN induced starved asteroids to feed **through** wire mesh, and also observed that they could extrude their stomach into prey that was situated at the bottom of a plasticine cylinder as high as the asteroids arms were long. However, one of the conspicuous traits of the normal feeding of *Asterias* is the very close application of the oral region to the shell edge at the point of penetration of the stomach lobes; indisputably the spines of *Hysteroconcha* would serve to prevent this, and therefore lessen the efficiency with which the two valves can be gripped and pulled apart by asteroids.

The spines must also help to protect against gastropod attack. When feeding normally *Hysteroconcha* lies with

just the spines and posterior part of the shell protruding above the substrate. A roving gastropod therefore initially makes contact with the spines, and in order to mount the bivalve and chip the edge off the valves (the normal technique of gastropods like *Busyon* and *Buccinum*) it would first have to dig the bivalve out of the substrate in order to get at the unprotected ventral margins. It is significant that in every case that I have seen of a *Hysteroconcha* which can be inferred to have been killed by muricid gastropods, the site of shell drilling has been on these unprotected ventral margins (Plate 5, Figures 2, 3, 5).

#### Concentric lamellae

It is far more difficult to postulate intuitively reasonable functions for the concentric lamellae than it is for the spines. As the anterior end of the shell is buried in the substrate during normal life, the only credible postulates will be related in some way to the burying of the shell, or to its stability when buried. One might distinguish three possibly discrete functions:

1. The lamellae assist the animal to bury itself.
2. The lamellae help to keep the animal stable in the substrate after it is buried.
3. The lamellae help to prevent the animal being dug out of the substrate by its invertebrate predators.

To be adapted for the first function, the lamellae would not be well developed at the anterior end of the shell, where they must add to the resistance encountered by the animal as it pushes into the sand; and they would perhaps be best developed mid-ventrally where they might be expected to help the "streamlining" of sand past the shell as the animal buried itself. Yet in *Hysteroconcha* the frills are always best developed at the anterior end of the shell and may (*H. lupanaria*) be obsolescent mid-ventrally.

It is difficult to dispute that the lamellae might have some stabilising effect in a sand substrate, if *Hysteroconcha* be compared with a similar shell not possessing lamellae. On the other hand, this is an extremely difficult proposition to test, and it does not seem reasonable to conclude at the moment that this is the primary function of the lamellae.

Again, it would seem possible that the lamellae – particularly in view of their strong recurved development at the anterior end of the shell, and in view of the known behaviour patterns of asteroids and gastropods – might serve as 'barbs' to prevent the shell from being drawn out of the substrate by such predators. But, to put it mildly, this is a relatively farfetched explanation.

I find none of these solutions totally satisfactory, and it seems likely that the correct interpretation will prove to be another as yet un-suggested explanation. It might

be that the combination of all three suggestions made here has some validity, but it is fair to conclude that, in our present state of knowledge, it is impossible to be sure of the exact function of the raised concentric lamellae. Indeed, the whole question of concentric ornament *sensu lato* is one that needs careful comparative study throughout the Bivalvia. The extremes of development of similar raised concentric lamellae in such groups as the Australasian *Bassina* must surely have some adaptive significance; exactly what significance is at the moment obscure.

### *Hecuba*

The adult shell is of comparable size to *Hysteroconcha*, a mature individual being about 75 mm long. It is of triangular shape with a conspicuous posterior carina delimiting the edge of the corcelet (Plate 7, Figure 13); there is a small escutcheon. Anteriorly the main disc carries spaced raised concentric frills which cease abruptly at the border of the large lunule. It is generally possible to recognise an inner and an outer lunule corresponding to the external shell tracks of the inner and outer lateral dentition. The inner ventral valve margins are weakly serrated, and provide a very inefficient interlock.

### ECOLOGY

I have no significant information on the ecology of this animal.

### DETAILED MORPHOLOGY

All specimens that I have examined are referable to the species *Hecuba scortum* (LINNAEUS, 1758); they mostly derive from Ceylon, India and the east African coast.

#### Spines

The posterior carina of this species is furnished with a set of spines analogous to the primary spine row of *Hysteroconcha* (Plate 7, Figures 13, 14, 17); there is no trace of a further secondary spine row. Unfortunately, the spines on the posterior carina are usually worn in the juvenile stages, making it impossible to ascertain at what stage they first appear. However, assuming that they were present as early as the first concentric frills, they were certainly present by the time the shell had reached a length of 3 mm. Thereafter the spines are introduced at regular intervals – about one every 2 to 3 mm in the adult. In large specimens the late spines become more and more crowded, and may be only 1 mm apart.

The spines themselves are fairly short (a long one measures just over 4 mm), broad at the base (the same spine is 3 mm wide at the base), and taper to a beautifully moulded point (Plate 7, Figure 14). They are not symmetrical about the carina, that portion anterior to the carina being markedly the broader (Plate 7, Fig. 13). The upper surface of the spine carries fine shell secretion traces, and a deep median furrow which runs out to the very tip of the spine. Underneath they are smooth with texture typical of internal shell surfaces, and carry a prominent keel (corresponding with the groove on the dorsal spine surface) that tapers away in the 'umbra' zone immediately ventral to each spine.

#### Concentric frills

The raised frills stretch from the edge of the lunule to a point almost exactly mid-ventral on the main disc. The interval between successive frills gradually increases with the size of the shell. In a specimen 37 mm long, the spacing between the two last-formed frills is 4 mm. There is a general correlation between individual spines on the carina and individual anterior frills: it is sometimes, though by no means always, possible to trace one into the other right across the shell (Plate 7, Figure 13).

The dorsal side of the frills carries typical concentric secretion traces and spaced shallow radial gutters corresponding to structural "frill ribs" on the ventral side of the frills (Plate 6, Figures 11, 12). This ventral side, like the ventral side of the spines, is texturally similar to internal shell surfaces. The frill ribs are about 1 mm apart, and correlated with this the shell surface between successive concentric frills carries low rounded radial ribs, each corresponding to a structural rib on the ventral side of the adjacent frill. These radial ribs, and also the frill ribs, become less conspicuous towards the central part of the disc and are not present at all on the zone between the posterior end of the frills and the posterior carina. The ribs are in no way related to the weak marginal interlocking.

### FUNCTIONAL INTERPRETATION

Because of the remarkable similarity of the basic structures, most of the comments on the process of secretion and the possible functions of the spines and concentric lamellae on *Hysteroconcha* apply equally well to *Hecuba*. However, there are differences and some difficulties.

#### Spines

The spines, though very beautifully moulded structures, are far shorter than is typical of *Hysteroconcha lupanaria*. However, of the possible functional interpretations, it is

the defensive paradigm that the spines of *Hecuba* most closely approach. Even so, there remain nagging doubts about the relatively short length of the spines; could they, in fact, be selectively effective?

This seems to be another case (biology is already littered with them, for example, the problem of the development of the vertebrate eye) where there is an intuitive difficulty in believing that the earlier, less well-adapted manifestations of a particular structure can possibly have carried any selective advantages. There is no doubt that a strong case can be made out for the defensive nature of the spines of *Hysteroconcha lupanaria*. But the closely related *H. dione* possesses spines that are morphologically almost identical except for their much shorter length. In fact, the spines of many *H. dione* are absolutely no shorter than those of *Hecuba*. It would obviously be foolish to attribute a different function to the spines of *Hysteroconcha dione* and *H. lupanaria*, and hence it is a reasonable suggestion that the same function will probably apply to *Hecuba*. The fact is that the *Hysteroconcha* spines, certainly in ontogeny and probably in phylogeny, have passed through a stage when they were absolutely no longer than the present adult spines of *Hecuba*. One should obviously be extremely careful before attributing a different function to each on the completely subjective judgement as to how long a spine must be before it acts as an advantageous defensive structure.

### Concentric frills

As in the case of *Hysteroconcha*, beyond the general postulate that the raised concentric frills (or laminae) are probably in some way concerned with the burrowing of the shell, or with its stability when buried, it is not possible to be sure exactly what their specific function is. However, granted the general postulate, it will obviously be advantageous for the concentric frills to be as strong as possible; in the case of *Hysteroconcha* this is achieved by having relatively thick laminae, but in *Hecuba* the same problem is solved by having thin frills together with strengthening frill ribs.

This is of considerable interest, for though it has often been suggested that radial structures in the Bivalvia are for strengthening the shell, it is rarely possible to demonstrate such a suggestion plausibly. The frill ribs do appear to be a genuine radial feature that results in structural strengthening. The overall appearance of the concentric frills and their frill ribs (Plate 6, Figure 12) is strikingly similar, and perhaps structurally analogous, to the fins of a fish. The radial 'ribs' on the shell surface between successive frills are clearly the result of secretion by the same strip of mantle that is responsible for the secretion of the frill ribs. Further support for a strengthening hypothesis

comes from the observation that the frill ribs become less well developed towards the centre of the main disc, and it is in just this spot that the frills themselves are most commonly broken. Similar frill rib structures can be seen in other groups of bivalves (*e.g.* Chamidae), and a strengthening interpretation may also be relevant in such cases.

However, the fact that the raised frills of *Hecuba* carry strengthening frill ribs does not of itself help to solve the problem of the function of the frills. Apart from the observation that muricid predation in *Hecuba* is also preferentially located on the unprotected ventral borders (Plate 7, Figure 15), it remains to conclude that a precise diagnosis of the function of this type of concentric ornament is not at present possible.

### CONCLUSIONS AND SUMMARY

This paper has discussed the morphology, and suggested functional interpretations, for 'ornamental' features on two of the more spectacular Recent bivalve genera. It could perhaps be maintained that the spines and frills of *Hecuba* and *Hysteroconcha* have no functional significance, but such an interpretation is too sterile. When one considers the remarkable convergent evolution implied by the gross homeomorphy of *Hecuba* and *Hysteroconcha* — two unrelated genera that live on opposite sides of the northern hemisphere — it becomes vanishingly improbable that their convergent structures are not in some way adaptive, and hence functional.

However, though it is obvious that much valuable analysis can be performed on dead shells, a satisfactory interpretation of many bivalvian structures can only be reached in conjunction with detailed studies of the living animal. Since the palaeontologist is never in a position to garner this type of additional data, except by the use of homological and analogical comparisons with living forms, it will be of interest to see how many of the essentially "palaeontological" arguments presented in this paper can be shown to be spurious, or irrelevant, when more is known of the modern *Hecuba* and *Hysteroconcha*. The lack of published information on the anatomy and habits of spectacular tropical mollusca remains as one of the largest gaps in modern understanding of invertebrate biology. Yet the functional interpretation of fossil and Recent Bivalvia is critically dependent upon the amount of information available on the biology of Recent species. All too often the assumption is made that because an animal is common, and its habits are locally well known, it would be undesirable to 'clutter up the literature' with the more pedestrian details of its ethology and mode of

life. I can only repeat my view, that it is these very pedestrian details that are so necessary for successful functional analysis, and that such details are conspicuous only by their rarity. One must hope for some fundamental contributions to this field of research in the near future.

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# Mode of Feeding and Diet, and Synthesis of Studies on Marine Pelecypods from Tomales Bay, California

BY

DON MAURER

Old Dominion College, Biology Department, Norfolk, Virginia 23508

## INTRODUCTION

THE PRESENT INVESTIGATION has a threefold purpose: 1) To describe the mode of feeding and diet of bivalves previously unreported; 2) To provide further evidence to interpret pelecypod-sediment associations described in an earlier study; 3) To synthesize field and laboratory work heretofore treated separately.

In a series of papers on marine pelecypods from Tomales Bay, California, I have been primarily concerned with the ecology of bivalves in relation to sediment and the interpretation of these relationships. More specifically, MAURER (1967) reported on the relationship between distribution, abundance, and size of *Tellina buttoni* DALL, 1900, *T. salmonea* (CARPENTER, 1864), *Mysella tumida* (CARPENTER, 1864), *Transennella tantilla* (GOULD, 1852), and *Lyonsia californica* CONRAD, 1837, to sediment type. In addition, MAURER (1967 a, 1967 b) described filtering and burial experiments respectively to explain the response of mollusks to sediment. One observation which emerged from these experiments was that, at least for a few of the pelecypods, the sediment might represent an important food source, or that their mode of feeding may be dependent on the type of substrate in which they live. If this is true some of the pelecypod-sediment associations recognized by the author might be accounted for.

STEPHEN (1928, 1929, 1930, 1932), HOLME (1949, 1961), YONGE (1949), SANDERS (1958, 1962), and POHLO (1966) have contributed information on feeding habits of tellinids. At present there are very few data on feeding of *Tellina buttoni* and *Tellina salmonea*, or, for that matter, on any of the other species treated in the study. The following discussion is restricted mainly to the tellinids and *Transennella tantilla* with some brief comments on *Mysella tumida* and *Lyonsia californica*.

## OBSERVATIONS

Siphons of *Tellina buttoni* are separate, long and flexible. The exhalant siphon is slender and tapers towards the aperture, while the inhalant siphon, which terminates abruptly, is more muscular than the exhalant siphon. On a conservative estimate, *T. buttoni* may extend its siphons four or five times the shell length which varied from 0.19 to 1.85 cm in length.

In an aquarium when *Tellina buttoni* burrowed into the substrate, it would gently test the sediment with its inhalant siphon and begin to inhale the substrate like an elephant's trunk. This feeding behavior of *T. buttoni* compares favorably with that of British tellinids described by YONGE (1949). *Tellina buttoni* has also been observed to probe the substrate with its inhalant siphon. Suction from its siphon disturbs sediment and causes fine matter to be raised into suspension. The mollusk then inhales the suspended particulate material.

During filtering experiments it was noticed that test animals would occasionally reach up with their inhalant siphons and take carmine particles out of suspension (MAURER, 1967 a). Nevertheless, the inhalant siphon was usually occupied with the bottom deposits or material raised by its movements into suspension just above the bottom.

During burial experiments *Tellina buttoni* would rarely, if ever, form any holes in the overlying clay (MAURER, 1967 b). And depending on the thickness of clay it would almost never extend its siphons above the clay-water interface. Following the burial experiments siphons of dead *T. buttoni* were frequently packed with clay and test animals that survived invariably contained some clay. For *T. buttoni* there was increased ingestion of clay with increased amounts of clay used in the experiments.

Concerning the diet of *Tellina buttoni* some preliminary observations can be offered. Diatoms were extremely abundant in outdoor aquaria where the clams were maintained. Upon dissection *T. buttoni* was found to be full of needle-like species of *Navicula*. This diatom lay obliquely in ctenidial chambers of the bivalves blocking water circulation. Other diatoms, *Coscinodiscus* and *Bidulphia*, were observed to be scattered throughout the alimentary tract and stomach. It is unknown whether *T. buttoni* ingests such large quantities of diatoms in nature. An unsuccessful attempt was made to identify stomach contents of freshly preserved material aboard ship. However, material found in feces of bivalves just after collection consisted of quartz, biotite, quartz diorite, schist, and the foraminifer *Elphidium*. An empty ostracod carapace was found in the area of the digestive gland of one of these mollusks. Several days after these pelecypods had been placed in aquaria with glass beads as substrate, they were examined and found to contain glass beads in the alimentary tract.

Several citations to feeding of tellinids in nature can be alluded to. For example, STEPHEN (1928) noticed that during the spring diatoms appeared almost exclusively in the gut of several species of *Tellina*. YONGE (1949) reported that a species of *Macoma* fed on deposits rich in diatoms. SANDERS *et al* (1962) listed a species of *Tellina* as containing sand, diatoms, and detritus in its stomach.

Both *Tellina salmonea* and *T. buttoni* have well developed longitudinal and transverse muscles in their siphons and a cruciform muscle that is characteristic of members of the Tellinacea (YONGE, 1949). The muscle is a sheath of fine, tough fibers attached ventrally to the base of the siphons and contributes to the flexibility and siphonal activity of forms with long siphons. Moreover, the siphons of *Tellina salmonea* are translucent, and as seen in *T. buttoni*, its siphons may extend 4 or 5 times the shell length which varied from 0.20 to 1.87 cm in length.

When *Tellina salmonea* was placed in aquaria without any substrate it would almost immediately raise its siphons up into the water. When sediment was present, its inhalant siphon would settle upon and probe the substrate, alternating continuously from water to substrate. For the main part siphons of *T. salmonea* were characteristically in the water as it would often function as a suspension feeder. Duality of feeding habit exhibited by this tellinid is even more marked than that of *T. buttoni*, and *T. salmonea* showed a preference for suspension feeding. HOLME (1961) has suggested a dual feeding habit for a British tellinid as he described the disposition of its siphons while feeding. He concluded that it may be able to feed as a suspension feeder and is probably not restricted

to a deposit feeding habit. POHLO (1966), who worked on *Tagelus californianus* (CONRAD, 1837), another tellinid which occurs in Tomales Bay, stated that it was not an active deposit feeder, but that it fed on suspended material. These references and my observations indicate that tellinids are not as restricted to a deposit feeding habit as was previously thought.

In filtering experiments *Tellina salmonea* had the lowest filtering rate (MAURER, 1967a). Yet it was commonly observed to inhale suspended carmine particles. Depending on the thickness of clay in the burial experiments *T. salmonea* would form holes in the heavy, viscous clay (MAURER, 1967b). This behavior was never observed in *T. buttoni*. Siphons of *T. salmonea* were rarely packed with clay, whereas siphons of the other tellinid were generally filled. ARMSTRONG (1965) described the difficulty encountered by clams covered by sand. Unless bivalves could extend their siphons through the new cover to the surface or maintain a sand free passage, they would perish. This might explain in part the high mortality of *T. buttoni* in the burial experiments.

Concerning the diet of *Tellina salmonea* it was observed to inhale copepods and the diatom *Coscinodiscus* which was extracted from the gills of this tellinid. These diatoms were also found in the stomach, and chains of diatoms were noticed in the digestive tract as well. Although *T. salmonea* was maintained in aquaria under conditions similar to *T. buttoni*, at no time was *T. salmonea* observed to be filled with diatoms or contain as much detrital material as *T. buttoni*.

Only a few general comments on the mode of feeding and diet of *Transennella tantilla*, *Mysella tumida*, and *Lyonsia californica* can be offered. Siphons of *Tr. tantilla* are short and free distally, but fuse proximally. Siphons contain frills or small tentacles around the apertures and this tentacular arrangement seems to be characteristic of many suspension feeders. In filtering experiments *Tr. tantilla* had a relatively high filtering rate and was seen to inhale suspended carmine and India ink particles. In burial experiments it suffered the least amount of mortalities and survived the rigors of the viscous clay. The fact that *Tr. tantilla* occurs intertidally to subtidally might be accounted for by its ability to remain shut for long periods of time, and thereby circumvent the deleterious conditions imposed by the overlying clay. The diatoms *Navicula*, *Bidulphia*, and *Coscinodiscus*, which were dissected from the other test species, were also found in *Tr. tantilla*. In addition, *Nitzschia* and *Melosira* were discovered within its gill system. These examinations were made on specimens that had lived in the outdoor aquaria for several weeks. Examination of specimens which had

remained in the aquaria a couple of days showed some glass beads, quartz, and shell fragments in their feces.

*Mysella tumida* was observed to feed on copepods and diatoms and the latter were dissected from the stomach. Upon dissection of *Lyonsia californica* no debris was found in its stomach. Other than this no observations were recorded on diet or mode of feeding of *L. californica*. KELLOGG (1915) briefly described and figured *L. saxicola* (BAIRD, 1863) and he stated that its ciliary mechanism was very similar to that of *L. californica*. On this tenuous basis it is provisionally suggested that *L. californica* is a suspension feeder.

## DISCUSSION

Results of field studies by SWAN (1952), PRATT (1953), PRATT & CAMPBELL (1956), and KRISTENSEN (1957) indicated that size of *Mya arenaria* LINNAEUS, 1758, *Venus mercenaria* (LINNAEUS, 1758) and *Cardium edule* LINNAEUS, 1758 may be strongly influenced by turbidity, rate of sedimentation, and nature of the substrate. Moreover, MAURER (1967) arrived at a similar conclusion concerning the distribution and abundance of *Lyonsia californica*, *Tellina buttoni*, *Tellina salmonea*, and *Mysella tumida* in Tomales Bay, California. Further it was revealed that the average size of the latter 3 species was statistically associated with sediment particle size. Laboratory studies referred to in ALLEN's (1963) review and especially the work of LOOSANOFF and co-workers showed the deleterious effects of increased sedimentation (organic and inorganic particles) on respiratory and feeding activities of *Mytilus edulis* LINNAEUS, 1758, *Crassostrea virginica*, and *Venus mercenaria*. About the response of different ctenidial types to filtering experiments it might be pointed out that *Mytilus edulis* is a filibranch, *Crassostrea virginica* is a pseudolamellibranch, and *Venus mercenaria* is a eulamellibranch; however, all feed as suspension feeders. Evidence on harmful effects of increased sedimentation to bivalves was provided by MAURER (1967a, b). Results of these experiments on mollusks from Tomales Bay agree generally with those cited from the literature.

Since the recognition of the pelecypod-sediment associations, one of the main objects of the investigation has been to obtain information concerning response of mollusks to sediment, in terms of food, protection, larval sites, and turbidity. From experiments and observations the author considers, at least for a few of the pelecypods, that sediment as a food source may dictate mode of feeding or that certain conditions of turbidity are related to the deposition of particular sediment types.

On the effect of turbidity on distribution, abundance, and size of clams it has been asserted that an increase or

inhibition of growth might be related to sediment. Pelecypods that live in turbid environments waste energy in clearing palps and gills from excessive particulate matter, produce greater amounts of pseudofeces, and consequently spend less time feeding. On the other hand, in a relatively clean environment the mollusks obtain maximal nutritional benefit of feeding time. Turbid conditions inhibit growth; clean conditions foster it. PRATT & CAMPBELL (1956) clearly stated this proposition in their study of *Venus mercenaria* and LOOSANOFF (1962) voiced a similar opinion. The present author considers this effect of sediment or sedimentation to be an important factor influencing the pelecypod-sediment associations with which he was concerned.

## SYNTHESIS OF FIELD AND LABORATORY STUDIES

For *Tellina buttoni* statistical analyses indicated that average size was positively associated with sediment size (MAURER, 1967). Laboratory work suggested some interesting features that might account for the association on the basis of turbidity tolerance and mode of feeding. Filtering ability of *T. buttoni* was generally high and it has been observed to inhale suspended material. Yet even with small concentrations used in the filtering experiments, *T. buttoni* commonly ingested more ink, carmine, and clay particles than *Tellina salmonea* and *Transennella tantilla*. In burial experiments *Tellina buttoni* again ingested large amounts of clay that it was generally unable to handle and these amounts were almost always greater than in the other test animals. Furthermore its production of pseudofeces was usually greater in heavier loads of clay. The relative amount of pseudofeces formed agreed substantially with that of other bivalves exposed to excessive amounts of material described by LOOSANOFF (1962). These mollusks were suspension feeders and had different ctenidial structures than *T. buttoni*. The preference of *T. buttoni* for silty-sand in light of laboratory work indicates that this species functions chiefly as a deposit feeder. The same evidence also indicates that there is a critical sediment size which inhibits growth. Sediment, which contains more than 30% silt and clay, is probably deposited in a turbid environment and is too densely packed to allow easy use of siphons to filter, feed, and digest efficiently.

For *Tellina salmonea* statistical analyses showed that average size was positively associated with sediment size (MAURER, 1967). Laboratory work revealed some interesting adaptations. As with *T. buttoni*, the association may be explained on similar grounds, that is, food and tolerance to turbidity. With *T. salmonea* the siphons were generally extended above the substrate, but were occasionally seen

to inhale bottom deposits. Contrary to this in the filtering experiments it had the lowest filtering rate and in the burial experiments *T. salmonea* was rarely full of clay. Distribution of this tellinid in substrates that range in particle size from silt through pebbles, particularly in the coarse sediment, suggests a suspension feeding habit. It was not clear whether *T. salmonea* was more sensitive to turbid conditions or had more difficulty inhaling large amounts of clay and silt than *T. buttoni*. On the basis of its more limited distribution in coarse sediment it is suggested that *T. salmonea* is more sensitive to turbid conditions than *T. buttoni*. When *T. salmonea* occurred in sediment with as much as 30% silt and clay, its size was limited and it was smaller than individuals which lived in sediment with little or no particulate material. In view of laboratory studies the preference of *T. salmonea* for detritus-free, medium sand to shell-sand indicates that this species functions as a suspension feeder in clean, coarse sediment and as a deposit feeder in fine substrates. This result tends to confirm suspicions raised by MAURER (1967 a) on possible dual feeding habit of *T. salmonea* and *T. buttoni*.

For *Mysella tumida* statistical analyses showed that average size was negatively associated with sediment size. From its distribution in sediment types comparable to the distribution of *Tellina buttoni*, and its single performance in the filtering experiments, it is tentatively concluded that *M. tumida* can filter fine material better than the tellinids. Studies by BALLENTINE & MORTON (1956) showed that a closely related genus was a suspension feeder which could feed selectively on diatoms. It appears that the distribution, abundance, and size of *M. tumida* is influenced by sediment size. However, its negative association with sediment size indicates that conditions of turbidity or sediment as a source of food do not have the same effect on *M. tumida* as they do on the tellinids.

Average size of *Transennella tantilla* did not show a significant association with sediment size (MAURER, 1967). Its ubiquitous distribution in the bay seemed to illustrate its independence from characteristic sediment types. Laboratory work did not disclose any dual feeding habit as was noticed in the tellinids. Relatively high filtering efficiency, low mortality rate and absence of clogging in burial experiments, tentacular frill work on siphons define *Tr. tantilla* as a suspension feeder. It was concluded that sediment does not exert a controlling influence on distribution, abundance, and size of *Tr. tantilla* as it does on the tellinids and *Mysella tumida*.

Although *Lyonsia californica* had no significant pelecypod size - sediment size associations, its maximal distribution and abundance were found to be in mud with 85% to 100% silt and clay. It appears that *L. californica* is adapted to extremely turbid conditions and heavy sedi-

mentation encountered in the southern portion of the bay. The nature of these adaptations has not been examined, but work on the functional morphology of its feeding apparatus would probably explain its rather restricted occurrence in very fine sediment.

## ACKNOWLEDGMENTS

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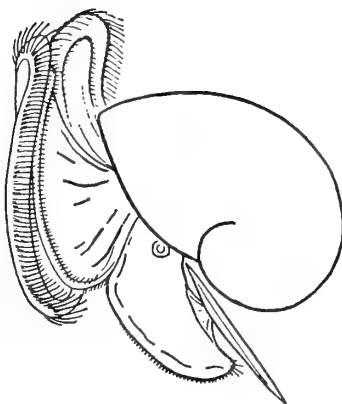
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# The Behavioral Role and the Structure of the Aesthetes of Chitons

BY

PAUL OMELICH

Electron Microscope Laboratory, University of California, Berkeley, California 94720

(Plates 8 and 9)

## INTRODUCTION

YOUNG AMPHINEURA OF THE ORDER Polyplacophora, commonly called chitons, have long been known to be negatively phototactic. During hours of daylight they are found under and between closely spaced rocks and in other places of relative darkness. Older chitons with worn and encrusted valves seem to be indifferent to the general illumination. The valves of chitons contain numerous sense organs. Due to their gross structure, these organs, called aesthetes, have been assumed to be photoreceptors by most investigators.

I have attempted to determine the function of the aesthetes by electron microscopy, electrical recording of nervous impulses, and behavioral observations.

## MATERIALS AND METHODS

### BEHAVIORAL

Observations regarding photoreception were made using a beam of light from a dissecting microscope lamp narrowed to an incident beam of approximately 3 mm diameter. The beam of light was directed onto different areas of the animals and their movements were observed.

Mechanoreception of the aesthetes was investigated by observing the movements of the animals while exposing their shell surfaces to touch of dissecting needles and a soft camel's hair brush.

In order to test chemical sensitivity of the chiton's dorsal surface, two thin glass cylinders were wax-sealed to the valves on each side of *Mopalia lignosa* (GOULD, 1846). The animals were placed on a marked glass plate and submerged in sea water so that the open end of the glass cylinders remained above the level of the water (Plate 8, Figure 1). Homogenates of the sea star, *Pisaster ochraceus*

(BRANDT, 1835), and mid-tidal red and green algae were made. The homogenates were placed in contact with the surface of the shell by partially filling the glass cylinder on one side of the animal. The cylinder on the other side was always filled with unaltered sea water. Movement of the animal, toward or away from the side exposed to the homogenates, was observed. In addition to the homogenates, dilute hydrochloric acid was placed in one of the cylinders and the animals were observed.

### ELECTRICAL RECORDING

I first attempted to record the mass electrical response from the whole animal with amplifier and oscilloscope. The chiton was immobilized between two chambers filled with sea water with light-shielded electrodes placed in each. Alternate exposure to light and darkness of the dorsal surface of the valves produced no recognizable change in the large slow muscle potentials continually seen. Isolating the anterior valve alone between the two sea-water bathed electrodes likewise produced no pattern related to exposure to light. Glass capillary microelectrodes with tips of approximately 20  $\mu$  diameter were placed over individual microaesthete caps and unit recording was attempted. Here again no impulses could be detected. Fine insulated steel recording electrodes were then introduced into the main aesthete nerve canals of broken valves and only photoelectric effects, probably of the electrode itself, were observed. Due to these repeated failures at electrical recording from the aesthetes I did not pursue this approach further.

### ELECTRON MICROSCOPY

*Mopalia lignosa* (GOULD, 1846), *M. hindsii* (REEVE, 1847), and *Tonicella lineata* (WOOD, 1815) were the three chiton species used throughout this work. All were ob-

tained along the California coast from Monterey to Point Arena. Shells were broken into fragments of less than 0.5 mm<sup>3</sup> and immediately fixed in 1% osmium tetroxide in sea water for 30 minutes to one hour at 0 to 5°C. Following fixation they were rinsed with sea water and decalcified in a 5% solution of ethylene-dinitrilo-tetraacetic acid in sea water for periods of 12 to 24 hours. Dehydration was in a graded series of ethanol. Some of the tissues were infiltrated with Araldite and some with Epon. Sections were cut with both diamond and glass knives on a Porter-Blum microtome. Both unsupported and Formvar-coated copper grids were used. The sections were examined with an Akashi TRS-50E1 electron microscope.

Potassium permanganate in sea water and acetate-veronal buffered osmium tetroxide fixatives were used, but without success. In addition, double fixation with 1% osmium tetroxide in sea water, before and after decalcification, was done. Here the processing resulted in destruction of much fine structure. Undecalcified shell fragments, fixed, dehydrated and embedded in hard Epon were sectioned with a diamond knife, but the ultrathin sections disintegrated upon the microtome trough. Thicker sections proved to be useless.

## RESULTS AND DISCUSSION

Probably all chitons with exposed valves possess organs, called aesthetes, embedded in the shell. These organs are apparently sensory and always occur in two sizes, megal-aesthetes and micraesthetes. There are no aesthetes of intermediate size. In addition to the aesthetes, some chitons possess larger organs branching from the same intra-shell nerves, called eyes. These eyes possess a cornea, lens and retina (MOSELEY, 1884 and 1885). None of the species of chiton on the California coast have been reported to possess eyes, but all species that I have observed or that other investigators have reported on have the two types of aesthetes.

## HISTORY

MARSHALL (1869) found in the shells of chitons canals of two sizes terminating in cup-shaped caps. He regarded the tissue found in these canals as respiratory in function. VAN BEMMEL (HUBRECHT, 1882) proposed that the organs found in these canals were homologous with the bundle of fibers supporting the spines of the girdle. MOSELEY (1885) reported that a Dr. W. B. Carpenter first observed the perforate structure of the tegmentum of chitons (date not specified). MOSELEY examined many alcohol-preserved chitons and found three types of organs: those which he called eyes, and two other similar, but much smaller structures. He named these smaller structures aesthetes. He thought the aesthetes to be organs of touch and the eyes to be photoreceptive organs. MOSELEY followed the pathways of the tubes leading from the eyes and aesthetes and he was of the opinion that they terminated in the parietal (pallial, branchial) nerves. The size of the eyes found ranged from 188μ to 42μ in diameter. The arrangement of the eyes varied from an irregular scatter to rows, either concentric or radiating to the apex of the tegmentum.

BLUMRICH (1891) made a microscopic study of the aesthetes of various chitons. He identified these organs as nervous structures and suggested they were probably photoreceptors. PLATE (1902) did an extensive study on the general anatomy of the chitons, including the aesthetes, but with apparently no new discoveries regarding the nature of these organs. NOWIKOFF (1907, 1909) did detailed anatomical work on the aesthetes and was convinced that they were nerves. LÉLOUP (1940) looked at the chitons of the California coast and noted the occurrence and gross appearance of the aesthetes, but did no microscopic work.

## BEHAVIORAL OBSERVATIONS

**Photoreception:** CROZIER & AREY (1918) found that a shadow of a fly 6 feet away caused *Chiton tuberculatus*

## Explanation of Plate 8

*Mopalia lignosa* (GOULD, 1846)

Figure 1: Chitons with glass cylinders attached for observations on chemoreception. cyl. - glass cylinders for receiving substances to be presented to the surface of the shell.

Figure 2: Photomicrograph of an aesthete complex. me - megal-aesthete; mi - micraesthete; cv - clear vacuoles; s - surface of shell. (x 590)

Figure 3: Electron micrograph of a longitudinal section through the megal-aesthete cap. tu - tubes of cap; mc - megal-aesthete cone material. (x 5500)

Figure 4: Electron micrograph of a cross section of the megal-aesthete nerve between or below the point of micraesthete branching. cv - clear vacuoles; nu - nucleus. (x 7500)

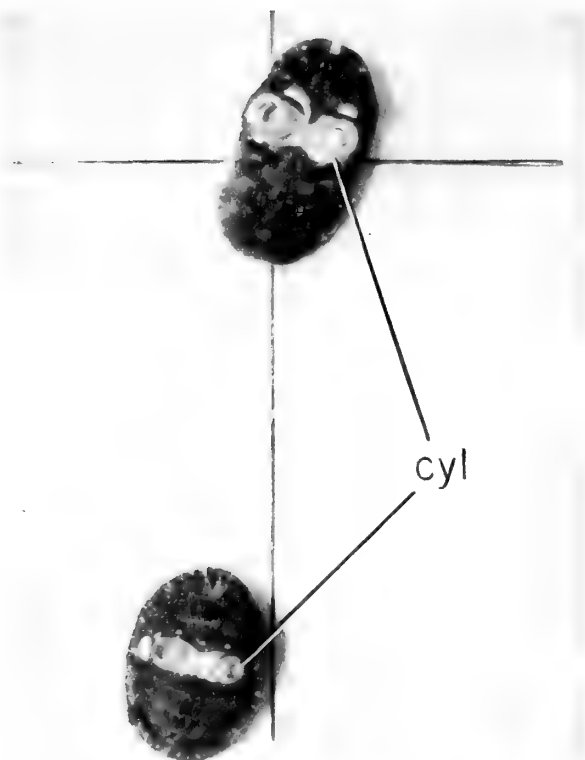


Figure 1

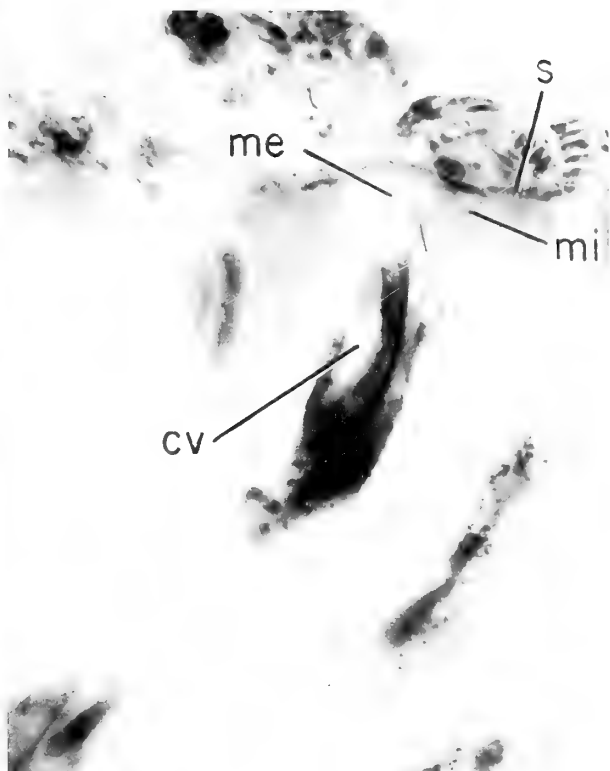


Figure 2

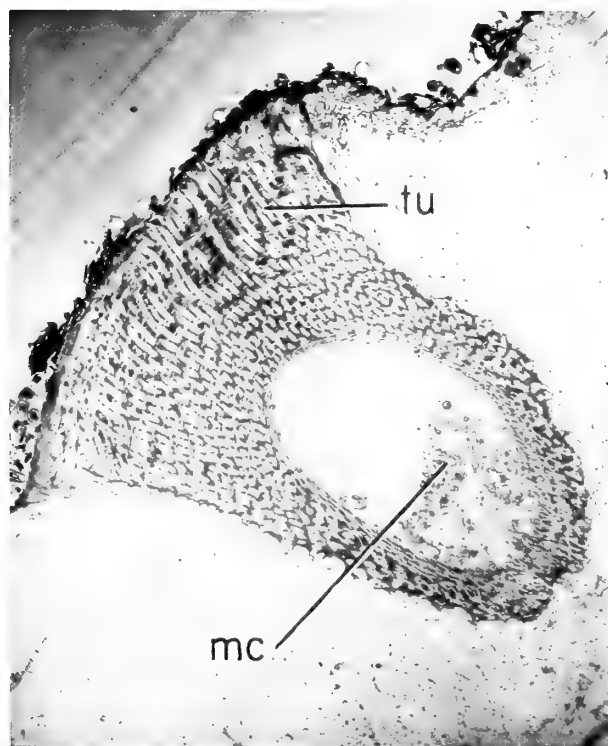


Figure 3

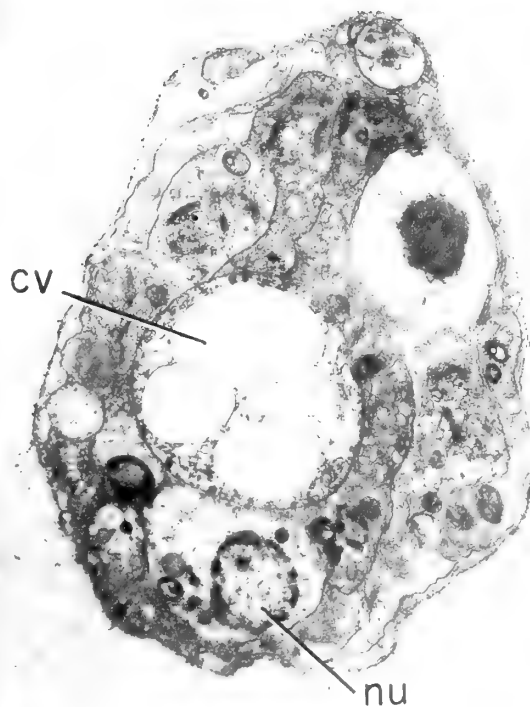


Figure 4



LINNAEUS, 1758, to halt motion temporarily! These authors stated that a miscellaneous collection of individuals may be caused to separate into two general size groups by sunlight, the larger moving into, the smaller away from lighted areas. The periphery of the girdle was found to be sensitive to a light increase, but the reaction was not oriented. Only a depression of the girdle to the substrate occurred. When they amputated the girdle the smaller chitons still oriented away from the light while the older ones went toward it.

HEATH (1899) observed the chitons of Monterey Bay, California and found that they remain out on their feeding ground only when the day is foggy or dark. He observed that *Ischnochiton magdalenensis* (= *I. heathiana* BERRY, 1946) adults are found under rocks during the day and only come out to feed at night.

CROZIER (1921) found an almost perfect correlation between the degree of erosion of chitons and the relative illumination of the situations frequented. Uneroded chitons were found to be photonegative even to moonlight. They were photopositive or indifferent when completely eroded. He found that the age of the animal was not important, only the degree of erosion.

DOUGLAS (1952) observed that the normal negative response to light exhibited by *Cyanoplax dentiens* (GOULD, 1846) depends upon the presence of all or most of its aesthetes. He removed the aesthetes of young photonegative *C. dentiens* by eroding their valves with emery cloth. These chitons were then often found in the direct rays of the sun along with older, naturally eroded animals.

I exposed portions of *Mopalia lignosa* to illumination from a narrow beam of light from a dissecting microscope lamp. A direct beam to any part of the girdle produced a clamping of the girdle to the substrate similar to that observed by other investigators. Illumination to one side of the valves only caused the animals to move away from the light. Illumination of either the anterior or posterior ends likewise produced a negative taxis.

It is remotely possible that the actual photoreceptors of chitons are not contained within the shell, but are located in the tissue beneath, the light being transmitted through the dense calcium carbonate of the valves. But this seems very improbable due to the relatively low intensities of light necessary to produce an oriented response. When only diffuse sunlight is allowed to enter through a slot into a blackened wooden box containing chitons, orientation is obtained (AREY & CROZIER, 1919) and the animals orient even to moonlight (CROZIER, 1921). It seems likely, therefore, that photoreception does occur in the shell of chiton. Because the aesthetes are the only nervous structures found within the shells it is quite probable that they are photoreceptive.

**Mechanoreception:** MOSELEY (1885) believed that the aesthetes were tactile organs. He thought this on the basis of the slightly protruding caps which he observed on the aesthetes. AREY & CROZIER (*op. cit.*) state regarding the aesthetes, "Definite evidence as to their functional significance has been completely lacking." They did comprehensive tactile, chemical and light behavioral work on *Chiton tuberculatus*. They concluded that in this species "There are no tactile receptors in the shell plates." But regarding another kind of chiton they observed minute projecting hairs on the valves, and they stated (without describing the methods used), "We find that the tegmentum of *Ischnochiton purpurascens* (ADAMS, 1845) is very sensitive to touch."

I tested *Mopalia lignosa*, *M. hindsii* and *Tonicella lineata* for mechanoreception. Lightly dragging a steel dissecting needle across the surface of the shells consistently produced a clamping reaction of the girdle to the substrate. But brushing with a camel's hair brush produced no effect. It seems likely that the response found as a result of touching with the hard steel needle is probably a result of shell distortion or vibration, or both, being transmitted to the foot and girdle where no doubt mechanoreceptors are found.

My longitudinal sections of the megal aesthete caps show them often slightly elevated above the surface of the shell (Plate 8, Figure 3). The micraesthete caps are consistently depressed. MOSELEY (1885) and BLUMRICH (1891) showed both the megal- and micraesthetes slightly elevated from the surface. NOWIKOFF (1909) saw them level with the shell. The position of the caps higher than that of the shell surface is not a prerequisite to mechanoreception, but touch receptors firmly fixed on their peripheries to the hard calcium carbonate of the shell and not protruding above it would most likely operate by recording minute distortions of the shell as do campaniform sensilla of the insect cuticle. But this does not seem likely due to the extreme hardness of the valves.

While this investigation did not conclusively prove that either the megal aesthetes or the micraesthetes are organs of touch, it seems to me that it is very unlikely that they function in this way.

**Chemoreception:** BARNAWELL (1960) found that in their natural habitat several species of chitons of the same types which I used eat food in the following order of total quantity:

1. Algae (red and brown)
2. Diatoms
3. Bryozoa
4. Hydroids
5. Barnacles
6. Sponges and mollusks

FEDER (1959) studied the food of the starfish *Pisaster ochraceus* (BRANDT, 1835) and stated that *Pisaster* was observed to feed primarily on gastropods and chitons.

Thinking that exposure of the surface of the valves of chitons to extracts of their most favored food and their common predator might reveal the possession of chemoreceptive function of the aesthetes, I applied homogenates of algae and starfish to the surface of one side of the shell only, one substance at a time (Plate 8, Figure 1). The glass cylinders containing the materials protruded above the surface of the water so that none of the homogenates could reach any other receptor areas of the animals. The cylinder opposite the food- or predator-filled one was filled to the same level with sea water from the chiton's habitat tank. Exposure of the shells to algae, starfish extract and dilute hydrochloric acid did not produce a visible response. Then I dropped several drops of the algae onto the girdle on one side only. Again there was no response. But when I dropped the starfish extract onto the mantle the animals initiated motion anteriorly and slightly away from the exposed side. Dilute hydrochloric acid evoked the same responses as the starfish extract, only more pronounced. These experiments were repeated a sufficient number of times to justify the conclusion that it is improbable that the aesthetes are chemoreceptive organs for the materials tested.

**Microscopy:** Invertebrate photoreceptors are much more diverse than vertebrate ones. They comprise several different structural types with only a few common features. Electron microscope studies have generally concentrated on the "higher" invertebrate phyla. Much work on the arthropod ommatidia and the cephalopod retina has been done. Aside from the Cephalopoda little work has been done on mollusks. I think that this investigation is the first attempt to ascertain the fine structure of the presumed photoreceptors in the Amphineura. The aesthetes of chitons are thought to be photoreceptors only because of behavior and gross structure. Therefore I prepared these organs for electron microscopy.

The invertebrate photoreceptor region is generally composed of cells containing organelles called rhabdomeres. These rhabdomeres in mollusks and in many other invertebrates contain pigment granules. In addition, the rhabdomeres are composed of an array of tubules and microvilli

probably derived from cell membranes. The average rhabdomere tubule is approximately 600 Å in diameter (MOODY, 1964). EAKIN (1963) adds the generalizations that many mitochondria are situated near the light sensory apparatus and that an axon-like fiber leads from the basal end of the receptor cell. EAKIN (*op. cit.*) states that in the annelid-arthropod-mollusk complex a fibrillar and centriolar assembly like that of the vertebrate photoreceptor cilium has not been seen. MILLER (1958) found an exception to this generalization in the ocellus of the scallop *Pecten irradians* LAMARCK, 1819. Here he found ciliary filaments leading into the bases of the lamellae.

MILLER (1960) described the tubular units of rhabdomeres in general as varying in diameter from 0.04-0.12 μ. He looked at *Pecten ocelli* (1958) and described globular appendages that are derived from cilia. Irregular matted microvilli extended from the photoreceptor cell. The diameter of these microvilli tubules was approximately 0.07 μ.

EAKIN (1963) studied the eye of the garden snail *Helix aspersa* MÜLLER, 1776, and found the photoreceptor cell studded with microvilli, each about 0.1 μ in diameter. The microvilli are radially arranged parallel to the long axis of the cell. They extend as much as 12 μ to the surface of a large structureless lens. No ciliary or centriolar apparatus was found.

WOLKEN (1958) looked at the retinal structure of *Octopus* and *Sepia*. He found the retina made up of rhabdomes analogous to those of the arthropod eyes. Each rhabdome consists of four visual units radially arranged. These units contained regularly arranged tubules approximately 0.05 μ in diameter. A central space containing pigment cells with screening pigment granules separated the rhabdomes. ZONANA (1961) saw *Sepia* microvilli of an average diameter of 0.1 μ.

In this investigation light microscopy showed that the general arrangement of the aesthetes of *Mopalia lignosa* is similar to that found in chitons by other researchers in that two types of organs are present, the smaller micraesthetes branching from the megalaesthete (Plate 8, Figure 2).

Electron microscopy revealed some new detail. The megalaesthete cap in longitudinal section (Plate 8, Figure 3) shows a regular tubular honeycomb extending from the surface of the shell almost to the center cavity. This

### Explanation of Plate 9

*Mopalia lignosa* (GOULD, 1846)

Figure 5: Electron micrograph of a longitudinal section of the aesthete nerve below the branching of the micraesthetes. nf - neurofibrils; pi - pigment granules. (x 20000)

Figure 6: Electron micrograph of a longitudinal section of the aesthete nerve farther down than that of Figure 5. nf - neurofibrils; pi - pigment granules. (x 22000)

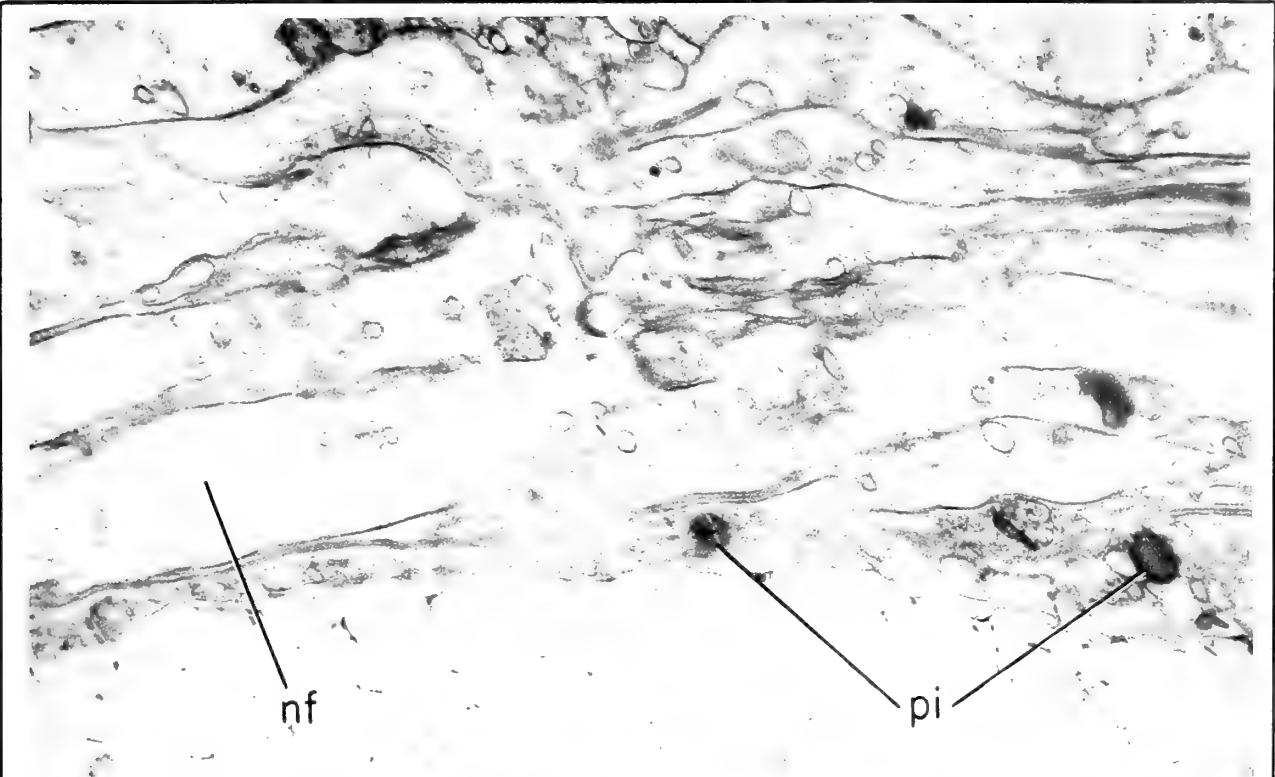


Figure 5

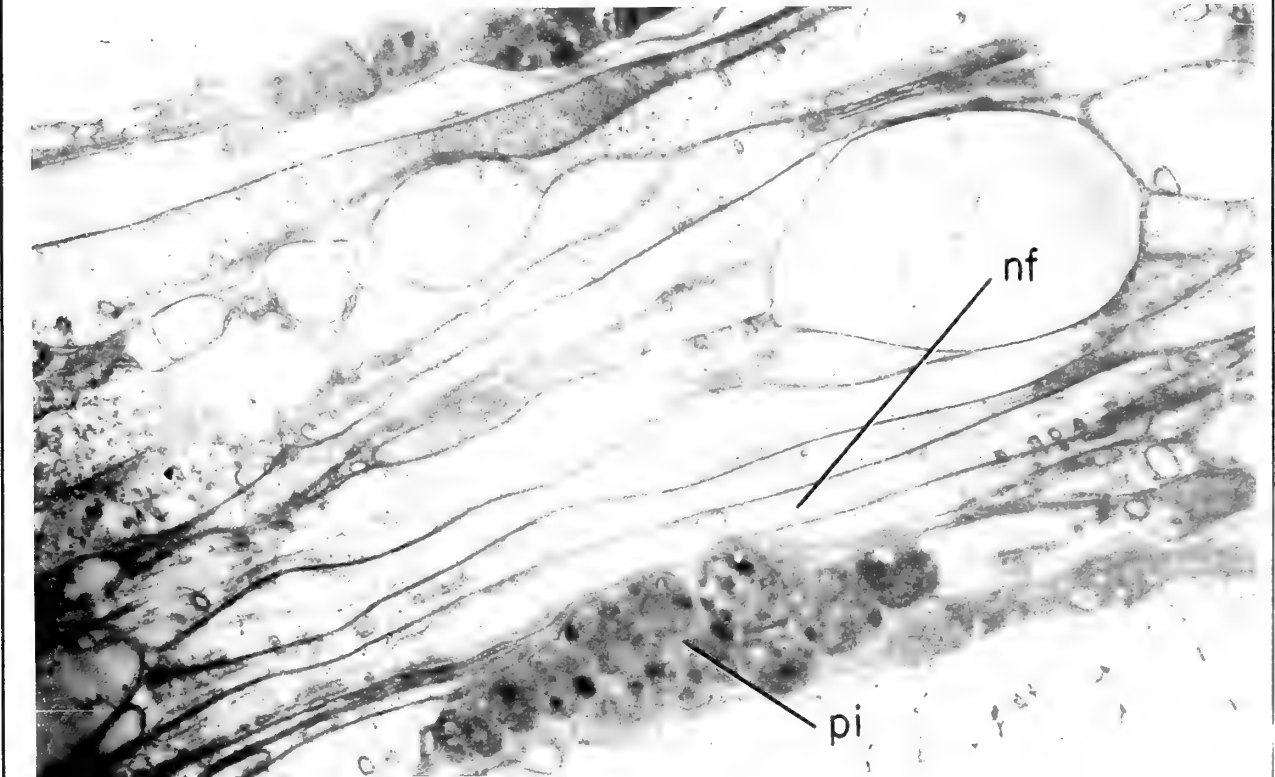


Figure 6



cavity under the cap is partially filled with a mass of what appears to be tubules extending from a central body which I called the megal aesthete cone because thick sections and light photomicrographs show the outline of this material as conical in shape. A finely structured layer seems to line the cavity. The micraesthete caps were similar in configuration, but smaller. They did, however, generally appear recessed from the shell surface in contrast to the slight protrusion of the megal aesthetes. MOSELEY (1885) saw both the megal aesthetes and the micraesthetes loosely occupying their canals and slightly protruding above the shell. Perhaps the dilute nitric acid he used for decalcification of the shell was the cause of this. BLUMRICH (1891) and NOWIKOFF (1909) saw the caps contiguous with the shell surface.

The tubular appearing structures within the aesthete caps are approximately  $0.06\mu$  in diameter. This is slightly larger than the smallest diameter of microvilli,  $0.04$ - $0.12\mu$ , as reported by MILLER (1960), but smaller than the  $0.25\mu$  microvilli of the polychaete *Nereis* (EAKIN, 1963). There seems to be a lack of protoplasmic connection between the cap itself and the megal aesthete cone material below. This cone with its tubules seems most likely to be the photoreceptive site, the microvilli radiating out into the cavity where light transmitted through the passages in the cap can be recorded. The cone tubules are slightly smaller than the cap passages and still within the range of invertebrate microvilli. Another possibility is that in better preserved material the tubules of the cone could be seen to continue out into the passages of the cap where the photoreceptive site would be even closer to the surface of the shell. Since no such connections were seen, this seems unlikely. But it is possible that the decalcification process destroyed connections to the cap passages. A less harsh method of removing the calcium carbonate should confirm this.

The cap material appears to be hard in nature and not primarily protoplasmic. It may be simply a special configuration of shell material which both protects the underlying sense organ and provides a light guide to increase sensitivity over what it would be if the receptors were embedded in ordinary shell.

Cross sections of the megal aesthete nerves show large clear vacuoles near the center (Plate 8, Figure 4). These vacuoles are also seen in photomicrographs (Plate 8, Figure 2) (BLUMRICH, 1891, NOWIKOFF, 1909). These vacuoles seem to be present in the nerve only at the point of micraesthete branching. Their function is unknown.

Longitudinal sectioning of the megal aesthete nerve reveals clumps of dense bodies, especially on the periphery

(Plate 9, Figures 5 and 6). Perhaps these are gliosomes within the cytoplasm of neuroglial cells. They appear similar to those found in the cockroach (PIPA, NISHIOKA & BERN, 1962). But until the fine structure of these dense bodies can be seen, I shall call them only pigment granules. Neurofibrils are characteristically seen in the presumed axons from the aesthetes.

## SUMMARY

Chitons possess organs in their shells which are apparently sensory. These organs, called aesthetes, seem to be photoreceptors. Behavioral tests indicate that it is very improbable that the aesthetes act as mechano- or chemoreceptors. Electrical recording from these organs did not give positive results.

Analysis of electron micrographs indicates that structures somewhat analogous to the microvilli of invertebrate photoreceptors do exist. A tubular structure, located in the caps of the aesthetes, was found. I believe that these tubes must either act as chambers for photoreceptive tubules similar to microvilli or as channels for transmission of light to receptor organs below. Since protoplasmic connections to the caps were not identified, it would seem that the photoreceptive material is located just under the cap. Tubules suggestive of microvilli were found there.

## ACKNOWLEDGMENT

Much of this study was done in the Department of Zoology, University of California, Berkeley, under the guidance of Dr. Donald M. Wilson. I am indebted to him for his help. The photographic work of Mr. Philip Spencer of the Electron Microscope Laboratory is very much appreciated.

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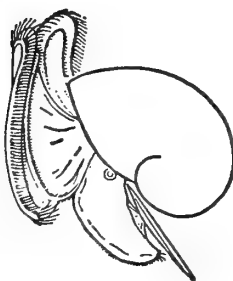
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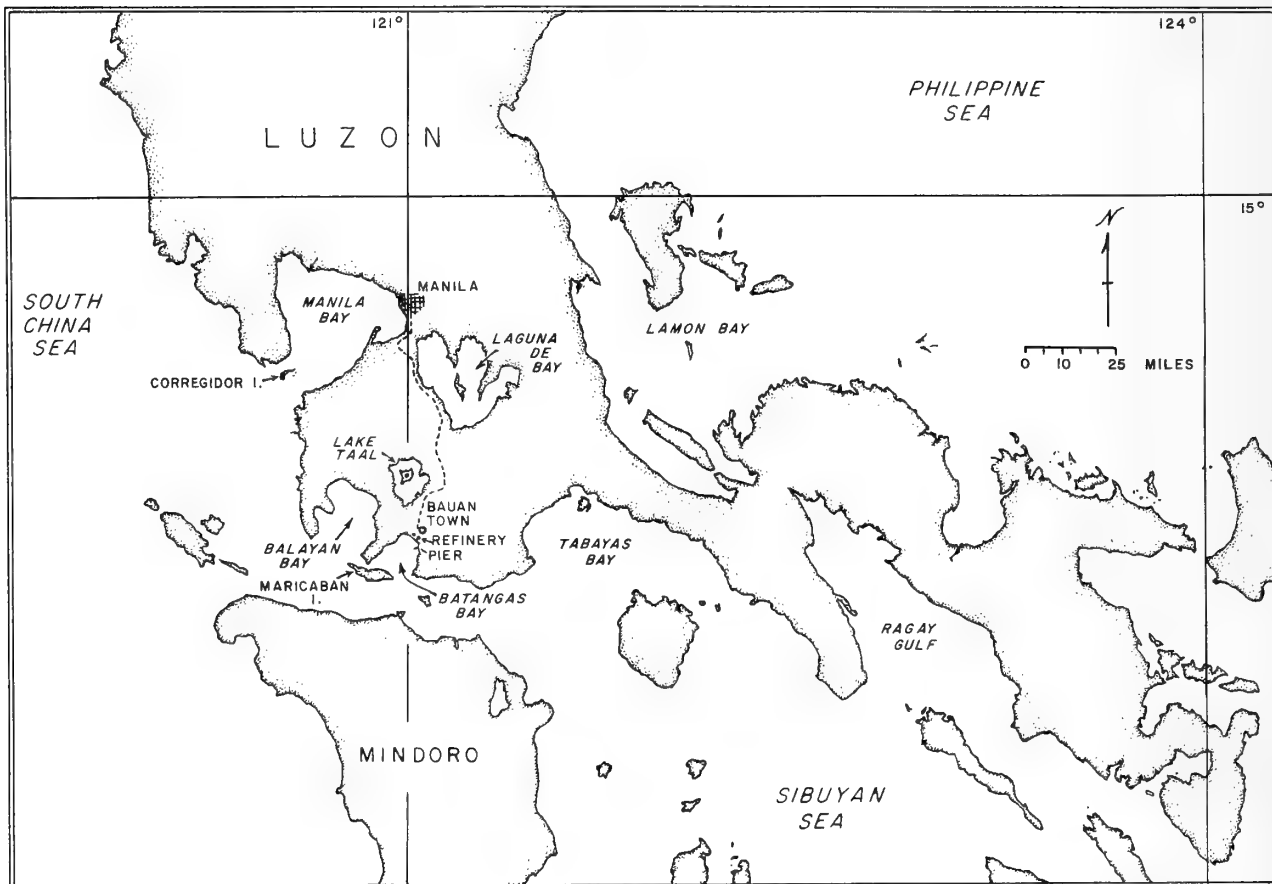
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## A Quantitative Sampling of the Mollusks of Batangas Bay, Philippines

BY

JEAN M. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plates 10 and 11; 1 Map; 2 Text figures)

ON A RECENT TRIP TO THE PHILIPPINES we had an opportunity to visit one of the world's most noteworthy collecting areas for mitrids, Batangas Bay in southern Luzon. We are greatly indebted to Mr. Fernando Dayrit for having arranged a day-trip to this area so that Mr. Cate and I could see it and sample the collecting there.

Two experienced divers employed by Mr. Dayrit (Plate 10, Figure 1) preceded us to the collecting grounds, and worked there for a total of three full days. With the exception of miscellaneous crabs, octopus and the like which they kept for food, we brought home with us their entire three-day catch. While we had expected to find a large number of mitrids in this material, as Batangas Bay is known to be one of the most productive areas in the world for this group, we were impressed by the large quantities and the diversity of other forms as well. This prompted me to put together the following checklist to record the various forms found, and to indicate their relative abundance within a comparatively limited area at that particular time. It should be stressed that this list is not intended to be a complete catalog of all mollusks that have been or are to be found in Batangas Bay, but merely of those collected during the three days in mid-November 1966 by the two expert divers.

Batangas Bay, situated about 100 kilometers south of Manila, is reached over a good paved road (see dotted line on Map). Our destination was Bauan Town; more specifically, the area in front of the CalTex refinery, where the company personnel graciously permitted us to park on the fenced and guarded property and to use the convenient supply of fresh water.

Batangas Bay is about 16 km wide at its mouth, and some 12 km long from the refinery area southward to the open sea; its depth (according to a hydrographic

chart) ranges to approximately 140 fathoms, though it seems fairly shallow near the shore and a long pier had to be built to accommodate oil tankers and other oceangoing vessels (see Plate 10, Figure 2). The collectors were free-diving in about 4 to 5 fathoms, approximately a mile or two south-southwest of the refinery (see Map).

The substrate is an extremely fine silty black mud several inches deep at the point where we attempted to collect in knee-deep water; it is probably of much the same type over most of the bay, judging by the material found clinging to the specimens brought in by the divers. To our disappointment at first, we found that the shallow water near the refinery was polluted by oil seepage, and the shells we were able to collect without swimming out into deeper, cleaner water were all dead. Furthermore, the nature of the substrate made it very difficult to see bottom after the silt had been stirred up by our wading, for great lingering clouds of suspended material obscured the view of any mollusk tracks or even of the bleached, white dead shells. However, our disappointment was soon forgotten when we saw the first sackful of mollusks spread out for our inspection by the divers; it is a tribute to their skill that they were able to locate so many small items that would ordinarily have been extremely difficult to find in the soft mud. Subsequent dives resulted in an array of specimens to satisfy the most exacting collector (see Plate 10, Figure 3): cones, terebras, turrids, bursas, cassis, harpas, strombids and many other forms were displayed before us, in addition to 23 species of *Mitra* and *Vexillum*. In all, 903 specimens were collected, representing 114 species in 33 families. I have listed them all below in systematic order.

The Mitridae provided the greatest number of species, with a total of 23; however, a number of these were

Table 1

	Number of	
	Species	Specimens
<b>GASTROPODA</b>		
Melaniidae	2	4
Thiaridae	1	1
Turbinidae	2	2
Architectonicidae	2	4
Cerithiidae	2	41
Xenophoridae	1	1
Strombidae	3	4
Cypraeidae	3	9
Naticidae	4	5
Cassididae	3	4
Bursidae	1	25
Tonnidae	1	5
Ficidae	1	2
Muricidae	2	3
Columbellidae	3	4
Cymatiidae	1	9
Buccinidae	5	50
Nassariidae	2	4
Fascioliariidae	2	4
Olividae	3	34
Mitridae	23	152
Harpidae	1	2
Cancellariidae	3	4
Turridae	7	118
Conidae	16	355
Terebridae	10	39
Atyidae	1	2
Ellobiidae	1	1
	106	888
<b>SCAPHOPODA</b>		
Dentaliidae	2	6
<b>PELECYPODA</b>		
Carditidae	1	2
Veneridae	1	1
Tellinidae	1	1
Psammobiidae	2	5
	5	9
Totals	113	903

represented by only a few specimens, so that the total of 152 mitrid shells came as a poor second to the Conidae, which had the second highest number of species (16), but an extremely high number of specimens (355).

The group of mitrids contained a few surprises for me in that certain species usually considered relatively common were represented by only one or two specimens (*e. g.*, *Mitra filaris* [1], *M. granatina* [1 dead] *M. clathrus* [2]);

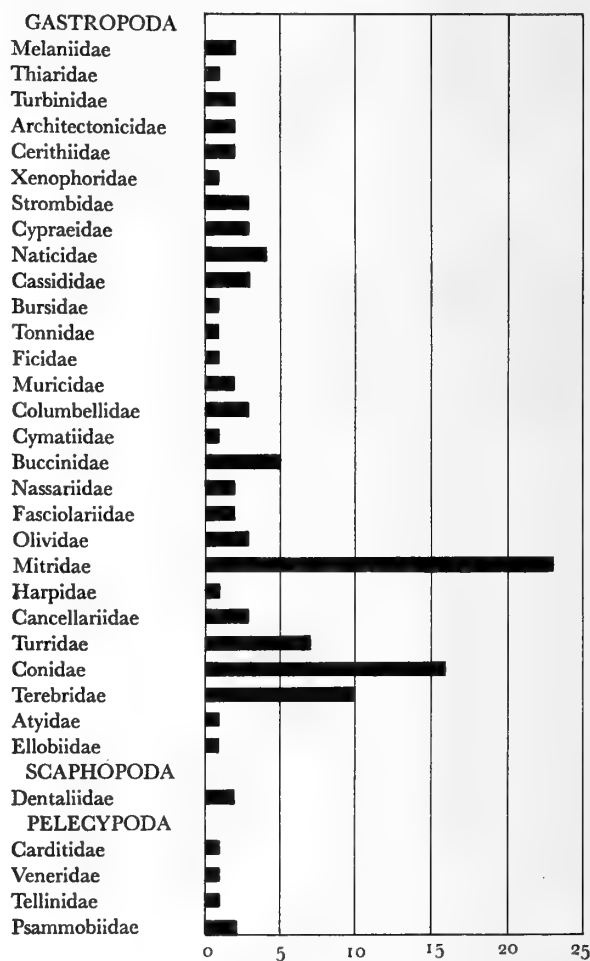


Figure 1

Illustrating the number of species in each family-group

### Explanation of Plate 11

Figures 1 a, 1 b: *Mitra suturata* REEVE, 1845 (x 3½)

Figures 2 a, 2 b: *Vexillum coccineum* (REEVE, 1844) (x ¾)

Figures 3 a, 3 b: *Vexillum ligatum* (A. ADAMS, 1853) (x 3½)

Figures 4 a, 4 b: *Vexillum marmorea* (A. ADAMS, 1853) (x 3½)

Figures 9 a, 9 b: *Pusia* spec. indet. (x 5)

Figures 5 a, 5 b: *Vexillum rectilaterale* (SOWERBY, 1874) (x 2½)

Figures 6 a, 6 b: *Vexillum rusticum* (REEVE, 1845) (x 3)

Figures 7 a, 7 b: *Vexillum spicatum* (REEVE, 1845) (x 3½)

Figures 8 a, 8 b: *Vexillum vulpecula* (LINNAEUS, 1758) (x 1¼)



Figure 1



Figure 2



Figure 3

Figure 1: Divers from Samar who collected the shells in this study

Figure 2: General view of Batangas Bay

Figure 3: Results of the first dive made by the two divers in Figure 1





Figure 1 a

Figure 1 b

Figure 2 a

Figure 2 b

Figure 3 a

Figure 3 b



Figure 4 a

Figure 4 b

Figure 5 a

Figure 5 b

Figure 6 a

Figure 6 b



Figure 7 a

Figure 7 b

Figure 8 a

Figure 8 b

Figure 9 a

Figure 9 b



Table 2  
Batangas Bay Mitridae included in the survey

Mitridinae:	Number of Specimens
1. <i>Mitra (Cancilla) clathrus</i> (GMELIN, 1791) (see CERNOHORSKY, 1965, plt. 14, fig. 25)	2
2. <i>Mitra (Cancilla) filaris</i> (LINNAEUS, 1758) (see CERNOHORSKY, 1965, plt. 15, figs. 33, 33 a)	1
3. <i>Mitra (Cancilla) flammea</i> QUOY & GAIMARD, 1833 (see CERNOHORSKY, 1965, plt. 15, fig. 29)	11
4. <i>Mitra (Cancilla) flammigera</i> REEVE, 1844 (see CERNOHORSKY, 1965, plt. 15, fig. 30)	24
5. <i>Mitra (Cancilla) granatina</i> LAMARCK, 1811 (see CERNOHORSKY, 1965, plt. 14, fig. 23)	1
6. <i>Mitra strigillata</i> SOWERBY, 1874 (see CERNOHORSKY, 1965, plt. 15, fig. 31)	15
7. <i>Mitra suturata</i> REEVE, 1845 (see Plate 11, Figures 1 a, 1 b)	1
8. <i>Mitra variegata</i> (GMELIN, 1791) (see CERNOHORSKY, 1965, plt. 14, figs. 24, 24 a)	9
Vexillinae:	
9. <i>Vexillum acupictum</i> (REEVE, 1844) (see CERNOHORSKY, 1965, plt. 19, fig. 81)	1
10. <i>Vexillum amanda</i> (REEVE, 1845) (see CERNOHORSKY, 1965, plt. 18, fig. 73)	13
11. <i>Vexillum coccineum</i> (REEVE, 1844) (see Plate 11, Figures 2 a, 2 b)	20
12. <i>Vexillum ligatum</i> (A. ADAMS, 1853) (see Plate 11, Figures 3 a, 3 b)	1
13. <i>Vexillum marmorea</i> (A. ADAMS, 1853) (see Plate 11, Figures 4 a, 4 b)	4
14. <i>Vexillum obeliscus</i> (REEVE, 1844) (see CERNOHORSKY, 1965, plt. 19, fig. 80)	10
15. <i>Vexillum radix</i> (SOWERBY, 1874) (see CERNOHORSKY, 1965, plt. 20, fig. 96)	2
16. <i>Vexillum rectilateralis</i> (SOWERBY, 1874) (see Plate 11, Figures 5 a, 5 b)	7
17. <i>Vexillum rusticum</i> (REEVE, 1845) (see Plate 11, Figures 6 a, 6 b)	1
18. <i>Vexillum semisculptum</i> (ADAMS & REEVE, 1850) (see CERNOHORSKY, 1965, plt. 18, fig. 67)	8
19. <i>Vexillum spicatum</i> (REEVE, 1845) (see Plate 11, Figures 7 a, 7 b)	3
20. <i>Vexillum todilla</i> (MIGHELS, 1848) (see CERNOHORSKY, 1965, plt. 21, fig. 104)	5
21. <i>Vexillum verrucosum</i> (REEVE, 1845) (see CERNOHORSKY, 1965, plt. 19, fig. 84)	4
22. <i>Vexillum vulpecula</i> (LINNAEUS, 1758) (see Plate 11, Figures 8 a, 8 b)	8
23. <i>Pusia</i> spec. indet. (see Plate 11, Figures 9 a, 9 b)	1
	152

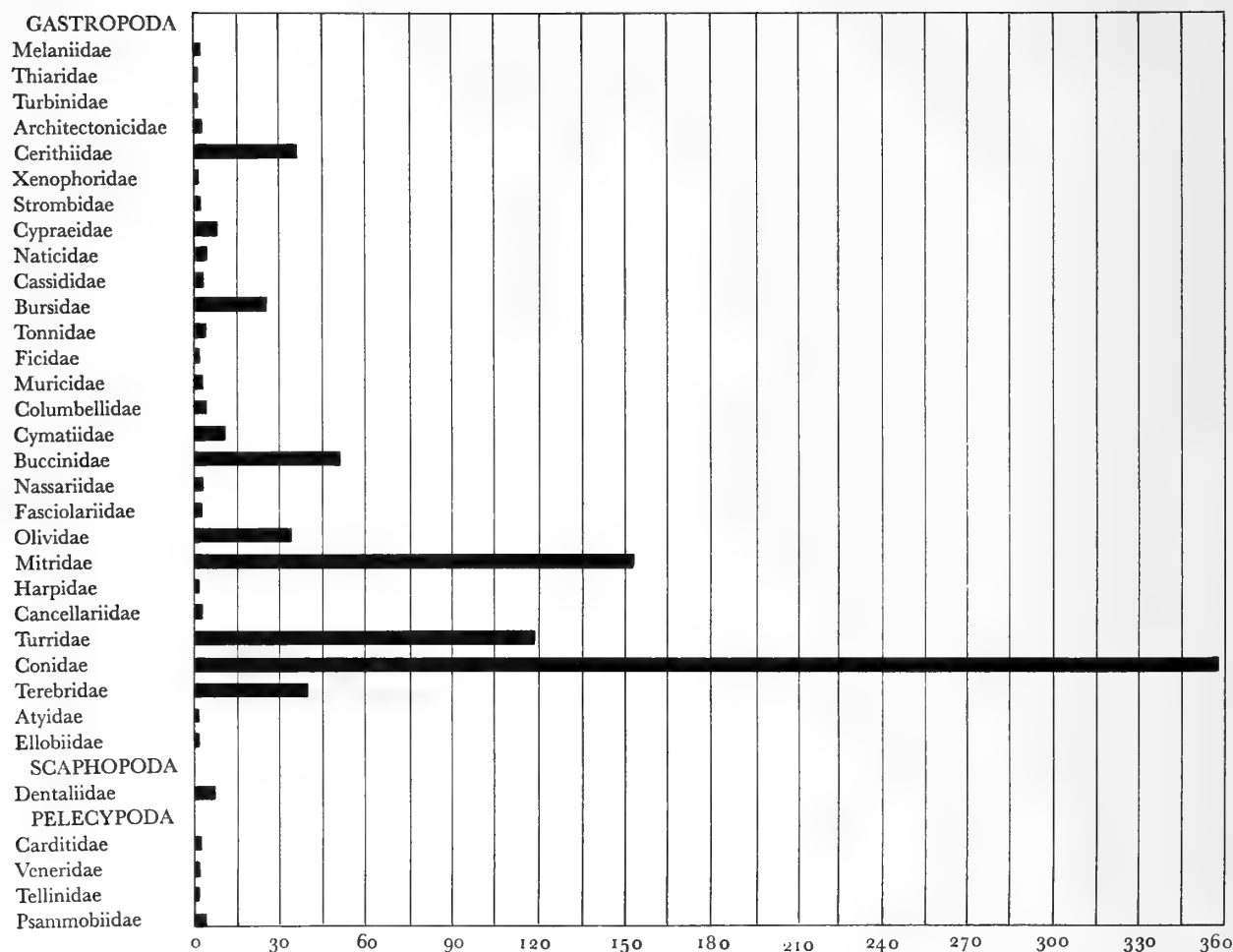


Figure 2

Illustrating the number of specimens in each family-group

conversely, relatively uncommon species were taken in greater numbers (*e. g.*, *Vexillum marmorea* [4], *V. todilla* [5], *V. verrucosum* [4]), and there were two forms that were entirely new to me, despite the fact that I already had a large amount of Batangas Bay material in my collection before visiting the area.

Table 1 indicates the number of specimens for each of the 33 molluscan families in the study; Text figure 1 illustrates the relative abundance of the various family-groups of shells found, and Text figure 2 shows the number of specimens.

Table 2 is a list of the mitrid species contained in this collection, the Mitridae being the only group for which I feel qualified to make specific identifications with reasonable accuracy. The reader is referred to CERNOHORSKY (1965) for illustrations of certain of these; otherwise the shells are illustrated here on Plate 11.

At least one specimen of each mollusk species included in the study will be preserved in a special-collection unit, so that subsequent work may be done on various groups as time permits, or as interested workers may wish to examine certain species.

I wish to thank Mr. Dayrit again for having made this trip possible, and Dr. Myra Keen for assistance in determining genera unfamiliar to me. The text figures and map are by Mrs. Emily Reid of The Veliger staff.

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*Epitonium (Asperiscala) billeeana* (DUSHANE & BRATCHER, 1965)  
non *Scalina billeeana* DUSHANE & BRATCHER, 1965

BY

HELEN DUSHANE<sup>1</sup>

SINCE THE PUBLICATION of the description of *Scalina billeeana* DUSHANE & BRATCHER, 1965, it has been suggested that the species was erroneously placed in the genus *Scalina*. CLENCH & TURNER (1951, p. 287) regard *Scalina* as a subgenus of *Amaea* while KEEN (1958, p. 278) treats *Scalina* as a full genus. Regardless of the course adopted, the species in question, *Scalina billeeana*, shows no particular affinity to either of these two generic taxa.

We are provisionally placing *Scalina billeeana* in the genus *Epitonium*, subgenus *Asperiscala* DE BOURY, 1909, which is characterized by fine spiral striae. The species "*Scalina*" *billeeana* differs from any known species of *Amaea* or *Scalina* in having an open umbilicus. It also differs in having a lighter, more fragile shell. The complete number of spiral ribs appears at a very early stage. In *Epitonium billeeana* the numerous spiral ribs are present on the third whorl with little appreciable increase in number on subsequent whorls, while *Scalina ferminiana* DALL, 1908 (p. 316; pl. 8, fig. 8) shows one strong spiral rib on the first three whorls, adding more spiral ribs in the following whorls until the final number is reached.

Another difference is the habitat. *Epitonium billeeana* occurs in shallow water and is parasitic on the coral *Tubastrea tenuilamellosa* (MILNE-EDWARDS & HAIME, 1848), while *Scalina* species are dredged on soft, silty mud bottoms.

In general proportions, *Epitonium billeeana* resembles *E. (Asperiscala) frielei* (DALL, 1889) (CLENCH & TURNER, 1952, p. 301, pl. 139), which also has an umbilicate shell with fine axial and spiral striae. *Epitonium frielei* is stated to be a flat white shell, while the living animal of *E. billeeana* is bright yellow and the shell is yellow tinted with a thin brown periostracum. Also, *E. frielei* has fewer costae and its spiral ribs are weaker; consequently, the relationship between the two species is probably super-

ficial. In habitat, *E. frielei* differs in having been taken in depths of 63 to 135 fathoms off the coasts of North Carolina and Florida.

*Epitonium billeeana* cannot be reconciled with any of the genera currently used for Eastern Pacific or Western Atlantic Epitoniidae but the author is reluctant to create a new genus for it until there has been a complete study made of the family names on a world-wide basis and the ecological relationships are better known.

Since the publication of the original description of *Epitonium (Asperiscala) billeeana*, additional localities for the species have been reported:

Bahía de las Animas, Gulf of California, Mexico.

Several live specimens with egg masses taken by diving at 5 to 30 feet, September 1965, Don Wobber, Hillsborough, California. — Reported as common.

Punta Colorado, Guaymas area, Sonora, Mexico. From siftings taken at extreme low tide, 1 beach specimen, November 1965, S. S. Berry.

Guaymas area, Sonora, Mexico. Dredged at 40 feet, one live specimen, Mrs. Camden Ernest, San Antonio, Texas.

Cape San Lucas, Baja California del Sur, Mexico. Five live specimens on coral taken by diving at 10 feet, April 3, 1966, James H. McLean. Size record: long. 24.6 mm, lat. 15.3 mm.

Manzanillo, Mexico. Five crab specimens taken by dredging at 17 fathoms, December, 1965, Laura Shy, Westminster, California.

This species can be expected to occur throughout the entire Panamic area in shallow water.

#### ACKNOWLEDGMENT

For critical reading of the manuscript and helpful suggestions I am indebted to Dr. James H. McLean.

<sup>1</sup> 15012 El Soneto Drive, Whittier, California 90605

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DALL, WILLIAM HEALEY

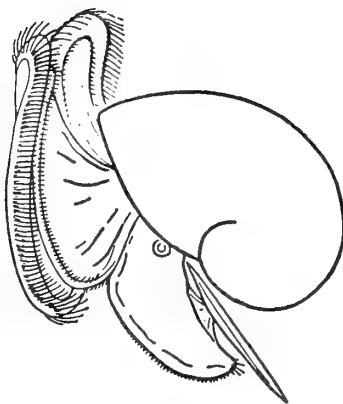
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## NOTES & NEWS

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### New Checklist in Preparation

BY

JUDY S. TERRY

Department of Geology, Stanford University  
Stanford, California 94305

A CHECKLIST of Recent marine prosobranch gastropods and pelecypods is being prepared for the U. S. Geological Survey with special emphasis on range and ecologic data to be used as a basis for biogeographic and paleoecologic interpretations of fossil assemblages. Depth, temperature, and kind of substrate are being recorded for live specimens or dead material which is likely to have lived recently in the habitat from which it was taken. For each species the following information will be given: reference to the original description and a good figure, catalogue number and repository of the type specimen, type locality, geographic range, the quality of material on which the range is based, ecologic data and a list of synonyms.

Ecologic and range data are expected to come from the literature, material in existing collections, specimens taken in dredging operations in connection with other U. S. Geological Survey, Bureau of Commercial Fisheries and state Fish and Game projects, and from collections and observations made at numerous marine stations along the coast of western North America. Range extensions and other pertinent information not reported in the literature are welcomed.

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### U. M. E. to Meet

It has just been announced that the third European Malacological Congress will take place in Vienna, Austria from September 3 through September 6, 1968. All malacologists are invited to attend. Detailed information may be obtained by writing to Dr. Oliver E. Paget, Museum of Natural History, Burgring 7, A-1014, Vienna, Austria. Inquiries should reach Dr. Paget as early as possible, but not later than August 31, 1967.

## Great Generosity of SAN DIEGO SHELL CLUB

The San Diego Shell Club a few weeks ago made a generous donation to *The Veliger*. This contribution has been used by the Editor of *The Veliger* to defray a part of the cost of the magnificent plates accompanying the paper on *Hysteroconcha* and *Hecuba* in this issue. We wish to express our appreciation as well as that of the author to the San Diego Shell Club.

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## BOOKS, PERIODICALS, PAMPHLETS

**The molluscan families Speightiidae and Turridae:  
an evaluation of the valid taxa both Recent and fossil,  
with lists of characteristic species.**

A. W. POWELL

Bulletin of the Auckland Institute and Museum, no. 5,  
184 pp., 23 pls., 179 text figures. November 1, 1966.

Some 549 generic and subgeneric taxa are listed in this long-needed work, with citation of original reference and type species of each and with notes on distribution. The Turridae and Speightiidae have diverged from Conidae and Terebridae, and a graphic frontispiece points up the relationships of the evolving groups since Mesozoic time. The introduction, an essay on morphology, is reminiscent of the one in a monograph on New Zealand Turridae published by Powell in 1942 but with added new material. He now has much more radular evidence available; in fact, he figures 169 radulae, 126 of these for the first time. Although there are other important anatomical features that are reviewed, the classification of the turrids still must be based primarily on shell characters, for these are all that we have for the fossil forms. Insofar as possible, Dr. Powell has illustrated all the type species of valid genera. As in his other papers, the line drawings and photographs are of excellent quality. An alphabetical index to generic and specific names is a useful feature of the work. This monograph will be immensely helpful to anyone who has to try to identify turrids – a puzzling group at best – or to deal with the problem of their classification.

MK

**Shell structure of patelloid and bellerophontoid gastropods.**

COPELAND MACCLINTOCK

Peabody Museum of Natural History, Yale University,  
Bull. 22, 132 pp., 40 pls., 128 text figs. February 21, 1967

Conventionally, the molluscan shell is described as being 3-layered, but MacClintock shows that there actually may be up to 6 distinct layers in some of the limpets. A large part of the material on which his studies are based – although this cannot be stated in the title – is from the West Coast. The layering in limpet shells comprises four types of structure – prismatic, foliated, and lamellar in two degrees of complexity. Numerous combinations are possible and MacClintock recognizes 17 for the species

“groups” that he has studied. Most of his species groups seem consonant with groups that modern workers recognize on the basis of soft parts, although there are some discrepancies. The study of shell structure may well provide a new tool to aid in the much-needed revision of West American limpets.

One advantage of a structural analysis is that when surface detail and coloring are lacking (as in most fossil limpets), a clue to placement may still be possible. MacClintock demonstrates this application by a study of the Paleozoic bellerophontids.

Illustrations in this work are of exceptional quality – text figures that are superbly drafted and photographic plates showing thin sections of shells under high magnification. The text is well written. MacClintock has made what could have been a forbidding technical paper into one that even the uninitiated can understand, and it should serve as a model for later investigations.

MK

**Valid zoological names of the Portland Catalogue**

HARALD A. REHDER. Proc. U.S. Nat. Mus., vol. 121  
(3579); 52 pp.; 1967.

In this very important paper REHDER points out that the names which are valid must be credited to Lightfoot, not to Solander or Humphrey. There are 62 available names out of a total of 111 proposed molluscan names; these are listed together with many pertinent data. A systematic list together with many synonyms is appended. Taxonomists will be grateful for this painstaking piece of work.

RS

**How to clean sea shells**

EUGENE BERGERON

Privately printed. Pp. 1-19 (Obtainable from the author,  
P. O. Box 1236, Balboa, Canal Zone; price \$1.50).

The relative advantages and disadvantages of 5 methods of removing soft parts from the inside of the shell and incrustations from the exterior are reviewed, and suggestions are made as to the best methods to be applied for various groups of mollusks, notably gastropods, pelecypods and chitons. The cover design on the pamphlet is a photograph that illustrates the effectiveness of one of the recommended methods in removing the soft parts intact; posed alongside the shells from which they had been extracted, the snail bodies look like replicas.

MK

**THE VELIGER** is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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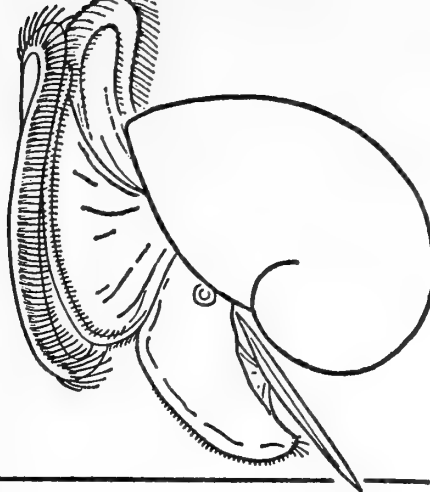
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

ORDER, Suborder, **DIVISION**, Subdivision, SECTION,  
SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).  
*New Taxa*

# Notes on *Morum dennisoni* (REEVE) and Related Species

(Gastropoda : Tonnacea)

BY

S. PETER DANCE

The Manchester Museum, The University, Manchester 13, United Kingdom

AND

WILLIAM K. EMERSON

Department of Living Invertebrates, The American Museum of Natural History  
Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 12)

THE PURPOSES OF THIS PAPER are threefold: (I) to identify and re-describe the holotype of *Oniscia dennisoni* REEVE, a rare and poorly known species from the West Indies; (II) to provide an annotated list of the names that have been applied to living representatives of the genus *Morum*; (III) to provide an annotated list of the fossil representatives of the genus *Morum* reported from the New World.

A new name, *Morum (Cancellomorum) watsoni* DANCE & EMERSON, is proposed herein to replace *Morum cithara* (WATSON, 1881), which is a secondary homonym of *Morum cythara* (BROCCHI, 1814).

## I. The Holotype of *Oniscia dennisoni* REEVE, 1842

REEVE's taxon was based on a single shell in the collection of John Dennison (?d. 1864), a leading British shell collector (REEVE, 1842, p. 212, pl. 253, figs. 5, 6). No locality information was provided. In the following year he published a description of the same shell, giving the measurements, "Long; 2. lat. 1 1/10 poll." (REEVE, 1843, page 91).

In 1858, Commandant Beau listed the species in a catalogue of the shells of Guadeloupe, West Indies (BEAU, 1858); subsequently HENRIK KREBS (1864, p. 35) cited BEAU's record in a catalogue of West Indian marine shells. Neither BEAU nor KREBS indicated the ownership of the specimens on which their respective records were based.

At the auction of the Dennison collection in 1865 two specimens were sold on the fourth day and are listed in the sale-catalogue as follows:

p. 33, Lot 665 "ONISCIA DENNISONI. This, and the companion lot 753, are exquisitely beautiful shells, in the finest possible condition, and it is supposed that no other specimens are at present known." (Anon., 1865).

p. 37, Lot 753 "ONISCIA DENNISONI, this and the other specimen are probably all that are at present known" (Anon., 1865). Lot 665 was purchased for 17 pounds and Lot 753 for 18 pounds; the names of the respective purchasers are unknown to us (DANCE, 1966, p. 210). In 1873, a specimen was sold at the auction of the collection formed by Thomas Norris (d. 1852) of Preston, Lancashire, and is listed in the sale-catalogue (of the second or "remaining" portion of the collection) as follows:

p. 17, Lot 757 "ONISCIA DENNISONI, a shell of extreme rarity" (Anon. 1873).

Neither the purchaser nor the price obtained are known to us (DANCE, 1966, p. 212). In 1876, one was sold at the auction of the collection formed by the Dutchman H. C. R. van Lennep (1820-1879) and is listed in the sale-catalogue as follows:

p. 12, Lot 161 "ONISCIA DENNISONI a great rarity (SOWERBY, 1876).

Again neither the purchaser nor the price obtained are known to us (DANCE, 1966, p. 193).

The few other shells of this species recorded in literature were collected after 1870 and must be dismissed from this inquiry.

On the basis of this admittedly scanty information, we consider that the holotype must be one of three shells; two of these are now in the British Museum (Natural History) and the other is preserved in the American Museum of Natural History. The smaller of the two in the British Museum once formed part of the collection of Hugh Cuming (1791-1865), acquired in its entirety by that institution in 1866 (DANCE, 1966, p. 167). It is labelled merely "*dennisoni*" and measures 31.7 mm in length and 23.0 mm in width. The larger shell once belonged to Mrs. de Burgh (*d.* 1881), a well-known collector whose shells, incorporated into the collection of V. W. MacAndrew (*d.* 1940), were acquired by the British Museum after MacAndrew's death (DANCE, 1966, p. 213). This shell too is labelled, by Mrs. de Burgh, merely "*dennisoni*" and measures 50.0 mm in length and 30.5 mm in width. The shell in the American Museum of Natural History once belonged to the English collector John Calvert, known for his magpie collecting activities in the late nineteenth and early twentieth centuries. In 1939, Calvert's collection of shells and other natural objects was bought by an American dealer and offered for sale in New York City (D'ATTILIO, 1950, p. 2). Among specimens from that collection obtained by Mr. Anthony D'Attilio and generously presented to the American Museum of Natural History were the type specimen of *Murex centrifuga* HINDS (EMERSON, 1960) and a specimen of *Morum dennisoni* (D'ATTILIO, 1955; EMERSON, 1967). The latter is undocumented and measures 53.5 mm in height and 30.5 mm in width.

The illustrations in the *Conchologia Systematica* (REEVE, 1842, pl. 253, figs. 5, 6) and the measurements given subsequently by REEVE (1843) are based on the same shell and are sufficient to eliminate the Cuming

specimen (Brit. Mus. No. 19671), as a contender for holotype status. The de Burgh and Calvert specimens, on the other hand, both approximate to the illustrations and measurements. We suggest that these were the two shells sold at the auction of Dennison's collection; that one came into Norris' possession (actually to a nephew, Thomas Norris [*?d.* 1873], who acquired the collection after his uncle's death) and one (possibly the same one) into van Lennep's; and that de Burgh and Calvert acquired one each. de Burgh probably acquired her specimen directly from the Dennison sale, Calvert his specimen from the van Lennep sale (de Burgh was collecting shells prior to the Dennison sale while Calvert seems to have become active rather later in the century). In 1919, J. C. Melvill (1845-1929) commented on the two Dennison specimens and said: "Type in the Mus. Brit.? . . . The specimen in the British Museum is, I presume, one of the two specimens then sold; what I believe to have been the other was offered by auction at Deventer, Holland, in July, 1876, at the sale of the Roeters van Lennep Collection, but I am ignorant of its destination" (MELVILL, 1919, p. 72). We have already shown that the Cuming specimen (the only one in the British Museum when MELVILL's paper was published) cannot be the holotype.<sup>1</sup>

Calvert's shell (Plate 12, Figure 7) is a well-preserved specimen, but it is slightly larger than the measurements given by REEVE (1842). It also possesses weaker plications on the shoulder of the body whorl and has a wider outer lip than that of the specimen figured by REEVE (*cf.* Figure 6 with 7 of Plate 12). On the other hand, the de

<sup>1</sup> In a footnote to the original description in *Conchologia Systematica* REEVE, (1842: 212) says: "we have been informed that there is another specimen in existence but in very poor condition." Although we have not been able to determine the identity of this "second" specimen, it cannot, in any case, be considered a paratype because it was not used in the preparation of the description.

### Explanation of Plate 12

Figures 1 to 3: *Morum strombiformis* (REEVE, 1842)

Figure 1: copy of original figure of holotype of *Oniscia strombiformis* REEVE, after REEVE, 1842, pl. 253, fig. 1; the width of the parietal callus is inaccurately shown in REEVE's illustration, *cf.* Figure 1 with Figure 2. Figure 2: Cuming specimen, holotype, in British Museum (Natural History), No. 1966723, no locality, photographs courtesy Dr. R. T. Abbott. Figure 3: immature specimen, in California Academy of Sciences, Loc. 1900, Cartagena Bay, Colombia, found dead on the beach, F. M. Anderson, collector. Figures approximately  $\times 2$ .

Figure 4: *Morum oniscus* (LINNAEUS, 1767), juvenile specimen, in American Museum of Natural History, No. 112483, from St.

Croix, Virgin Islands, G. Nowell-Usticke, collector;  $\times 2$ . Note the more inflated form, shorter spire, wider parietal callus, and coarser sculpture than in a specimen of about the same size and number of whorls of *Morum strombiformis* (*cf.* Figure 3).

Figures 5 to 7: *Morum dennisoni* (REEVE, 1842).

Figure 5: de Burgh specimen, holotype of *Oniscia dennisoni* REEVE, in British Museum (Natural History), No. 19601620, no locality. Figure 6: copy of original figure of holotype, after REEVE, 1842, pl. 253, figs. 5, 6. Figure 7: Calvert specimen, *ex* D'Attilio collection, in American Museum of Natural History, No. 128181, no locality. Figures approximately  $\times 2$ .



Figure 1

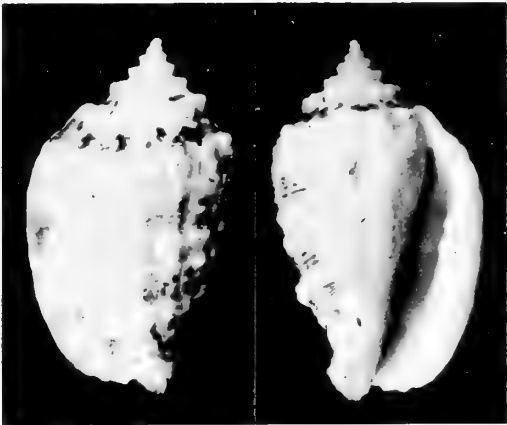


Figure 2

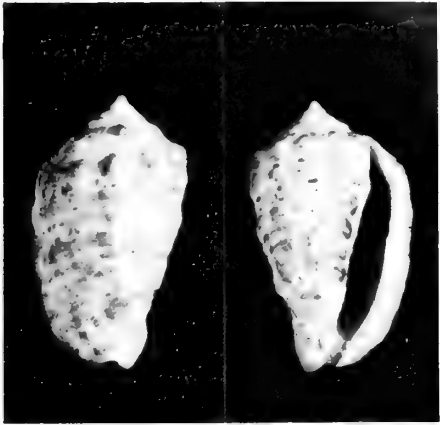


Figure 3



Figure 4

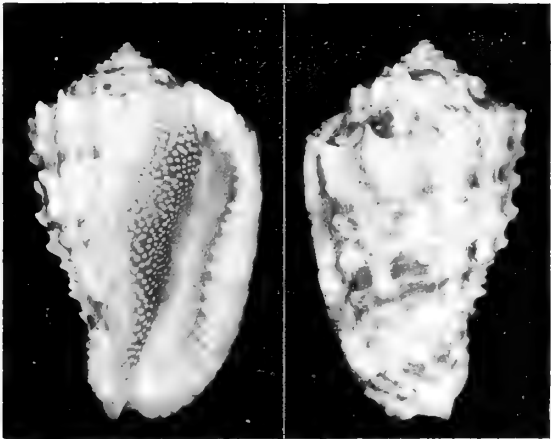


Figure 5

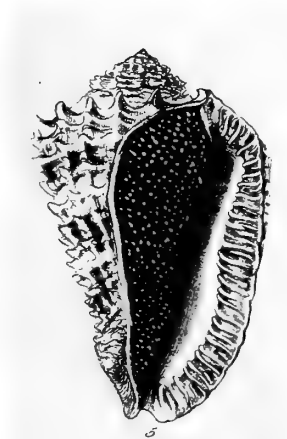


Figure 6



Figure 7



Burgh specimen, which is sparingly perforated in its upper whorls by a boring organism, has the same measurements as REEVE's figure, and it appears to be morphologically more like REEVE's original illustrations (*cf.* Figure 5 with 6 of Plate 12). Consequently, we consider the de Burgh shell to be the holotype of *Oniscia dennisoni* REEVE, 1842.

*Morum (Cancellomorum) dennisoni* (REEVE, 1842)

(Plate 12, Figures 5 to 7)

*Oniscia dennisoni* REEVE, 1842: 211, pl. 253, figs. 5, 6, no locality; REEVE, 1843: 91, no locality; REEVE, 1849, *Oniscia* pl. 1, fig. 6, no locality; BEAU, 1858: 7, Guadeloupe, Lesser Antilles; KREBS, 1864: 35, repeats BEAU's record.

*Oniscidia dennisoni* REEVE, DALL, 1889: 20, 231, Arrow-smith Bank, Yucatán, Mexico, in 130 fathoms, coral (U. S. N. M. 93742).

*Morum dennisoni* REEVE, MELVILL, 1919: 72; CLENCH & ABBOTT, 1943: 5, 6, pl. 4, fig. 5, Sandy Bay, Barbados, Lesser Antilles, in 75-100 fathoms, a poorly preserved specimen that may have been ingested by a fish (M. C. Z. 124699); DANCE, 1966: 193, 210, 212, 214, pl. 22c (figured specimen *ex de* Burgh Collection, B. M. N. H. 19601620).

*Morum (Cancellomorum) dennisoni* REEVE, EMERSON, 1967: 290, pl. 39, figs. 1a, 1b (specimen *ex* Calvert Collection, A. M. N. H. 128181).

**Type locality:** Guadeloupe Island, Lesser Antilles, designated by MAURY (1922 :119) and CLENCH & ABBOTT (1943: 6), on the basis of the record of BEAU (1858).

**Type depository:** Holotype, British Museum (Natural History), No. 19601620, *ex de* Burgh Collection.

**Description of holotype:** Shell triangularly ovate, imperforate, solid and strong; whorls seven, shouldered, and formed below the shoulder angle. Spire depressed, slightly produced. Whorls longitudinally compressed to form blade-like plications, cancellated with numerous narrow ribs forming small knobs which are longer and more produced on the shoulder of each whorl. Interspaces between nodose ridges with numerous axial threads crossed by fewer spiral threads. Parietal shield broadly expanded, thick, minutely pustulate; pustules weakly lincate. Outer lip reflected, thickened, denticulate along entire inner margin with irregular ridges. Base color whitish with 4 spiral bands of light brown on the body whorl and with irregular patches of brown on the spire, on the outer margin of the outer lip, and on the nodose ridges of the body whorl. Parietal shield a vivid reddish brown (blood-red on fresh specimens, *fide* REEVE, 1849), pustules whitish. Measurements 50.5 mm in length, 30.5 mm in width. Operculum not seen.

**New records** (specimens not previously reported in the literature):

S.S.E. of Freeport, Texas, in 34 fathoms, by shrimp net, Allen Knight, in 1962; one specimen, dead, faded and iron stained in collection of Mildred Tate; another dead specimen taken at the same time.

Off Pensacola, Florida, 30° 02' N, 86° 55' W, 64 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 353, May 25, 1951, one dead specimen, mud bottom.<sup>2</sup>

Off Tarpon Springs, Florida, 28° 15' N, 84° 53' W, 60 fathoms, dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 919, March 11, 1954, one live specimen, coral bottom, temperature 65° F.<sup>2</sup>

Off Strangers Cay, Bahamas, 27° 08' N, 77° 52' W, 160 fms., dredged by Bureau of Commercial Fisheries M/V *Silver Bay*, station 3474, October 25, 1961, one specimen, coral bottom.<sup>2</sup>

Off Matthew Town, Great Inagua Island, 20° 54' N, 73° 37' W, 88 fms., dredged by Bureau of Commercial Fisheries M/V *Silver Bay*, station 3502, November 5, 1961, two dead specimens, coral bottom.<sup>2</sup>

On eastern edge of Quita Sueño Bank, off Nicaragua, 14° 05' N, 81° 21' W, 100 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 4928, June 8, 1964, two dead specimens, coral bottom.<sup>2</sup>

Off Piña, Panama, 9° 19' N, 80° 25' W, 75 fms., trawled by Bureau of Commercial Fisheries R/V *Oregon*, station 3587, May 29, 1962, one dead specimen, mud bottom.<sup>2</sup>

Off Punta San Blas, Panama, 9° 38' N, 78° 57' W, 65 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 5735, October 19, 1965, one live specimen, rocky bottom.<sup>2</sup>

Off Punta Guaniquilla, Puerto Rico, 18° 03' N, 67° 27' W, 165 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 2643, October 5, 1959, one dead specimen, muddy bottom.<sup>2</sup>

West of St. Martin Island, 18° 14' N, 63° 20' W, 76 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 5919, February 25, 1966, one live specimen, sponge bottom.<sup>2</sup>

Off Calibishie, Dominica, 15° 37' N, 61° 22' W, 34 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 5920, March 3, 1966, two live specimens, sponge bottom.<sup>2</sup>

Off Anse Quancery, Dominica, 15° 25' N, 61° 12' W, 60 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 5933, March 5, 1966, two live specimens, rocky bottom.<sup>2</sup>

<sup>2</sup> Deposited in the collection of the U. S. Bureau of Commercial Fisheries, Pascagoula, Mississippi, *teste* Harvey R. Bullis, Jr.

Barbados, obtained by the Smithsonian-University of Iowa Expedition, in 1918; one beach specimen from station 411 (U.S.N.M., No. 459829), one fragmental specimen, station 483, 90-100 fms. (U.S.N.M., No. 459830).

Off east coast of Barbados, 13° 02' N, 59° 34' W, 123 fms., dredged by Bureau of Commercial Fisheries R/V *Oregon*, station 5015, September 20, 1964, one specimen, rocky bottom.<sup>2</sup>

96 miles N of Georgetown, Guiana [British Guiana] 08° 10.9' N, 57° 48' W, 53-60 fms., dredged by R/V *Chain*, station 35, cruise 35, R. W. Foster, April 28, 1963; one specimen with animal (M. C. Z., Harvard University, No. 262149).

Northeast of Paramaribo, Surinam, trawled by fishermen and purchased from them by Mr. T. H. Munyan, March, 1965; one live specimen in the collection of Mr. Munyan.

**Range:** Gulf of Mexico: off Freeport, Texas, Pensacola and Tarpon Springs, Florida, and Yucatán, Mexico; off the Bahama Islands: Strangers Cay and Great Inagua Island; Caribbean Sea: off Puerto Rico, Lesser Antilles, Nicaragua, and Panama; and off Guiana and Surinam, in the western Atlantic. Living specimens taken in 34 to 76 fathoms (median of 60 fathoms), on coral, rocky, and sponge substrates.

## II. Annotated List of Names that have been applied to Living Representatives of the Genus *Morum* RÖDING, 1798

### *Morum* (*sensu stricto*)

Type species: *Morum purpureum* RÖDING, 1798 [= *M. oniscus* (LINNAEUS, 1767)], by M.

*Strombus oniscus* LINNAEUS, 1767, Syst. Nat., ed. 12: 1210 [West Indies]. Type material presumed lost (*vide* DANCE, 1967, p. 22).

*Cypraea conoidea* SCOPOLI, 1786, Delic. Flor. Faun. Insubr., prt. 2, p. 78, plt. 24, fig. 3 [= *M. oniscus* (LINNAEUS) *vide* CLENCH & ABBOTT, 1943, p. 4].

*Morum purpureum* RÖDING, 1798, Mus. Bolt., p. 53 [= *M. oniscus* (LINNAEUS)].

"*Oniscia tuberculosa* G. B. SOWERBY," 1<sup>st</sup> of name, 1824, The Genera of Recent and fossil shells, *Oniscia*, p. 2 [*nomen nudum*].

*Oniscia tuberculosa* "SOWERBY" REEVE, 1842, Conch. system., 2: 211, *Oniscia* plt. 253, figs. 2-4 [eastern Pacific]. Type material presumed lost. Type species of *Plesioniscia* P. FISCHER, 1884, by M.

*Oniscia triseriata* MENKE, 1830, Syn. method. moll. gen. . . ., Ed. 2, p. 64 [= *M. oniscus* (LINNAEUS) *vide* CLENCH & ABBOTT, 1943, p. 4].

*Oniscia lamarckii* DESHAYES, 1844, in LAMARCK, Hist. nat. anim. sans vert., Ed. 2, 10: 12 [= *M. oniscus* (LINNAEUS)]. Not "*Cassidaria* (*Oniscia*, SOWERBY) *lamarckii*" [*sic*] LESSON, 1840, Rev. Zool. Paris 3: 212, from "Australia," an unrecognizable taxon according to MELVILL (1919, p. 70). The type of Lesson's taxon is not in the collection of the Muséum National d'Histoire Naturelle, Paris, *teste* Dr. Bernard Salvat (*in litt.*).

*Morum xanthostoma* A. ADAMS, 1854, Proc. Zool. Soc. London for 1853: 174 [= *M. tuberculosa* (REEVE)]. Lectotype (here selected) in British Museum (Natural History), No. 1966721, *ex* H. Cuming collection.

(*Herculea*) HANLEY, in H. & A. ADAMS, 1858

Type species: *Oniscia ponderosa* HANLEY, 1858, by M.

*Oniscia ponderosa* HANLEY, 1858, Proc. Zool. Soc. London, p. 255, plt. 42, figs. 9, 10 [western Pacific]. Lectotype (here selected) in the British Museum (Natural History), No. 1966724, *ex* H. Cuming collection. We do not agree with TRYON (1885, p. 282) that *Morum exquisita* (ADAMS & REEVE) is the same species; neither does it resemble *M. ponderosa*, which is characterized by a non-papillate parietal callus, sufficiently to be placed in the same subgenus.

(*Cancellomorum*) EMERSON & OLD, 1963

Type species: *Morum grande* (A. ADAMS, 1855), by O. D.

Until recently, the cancellate species of *Morum* were commonly referred to either "*Oniscidia*" (SWAINSON, 1840, p. 299) or to "*Onimusiro*" (KIRA, 1955, p. 43; 1959, p. 51), neither of which is an available name. As WOODRING (1959, p. 202) has pointed out, "*Oniscidia*" is based on an apparent *lapsus* made by SWAINSON for *Oniscia* SOWERBY, 1824, a fact first noted by HERRMANNSEN in 1847. *Oniscia*, together with *Lambidium* LINK, 1807, *Ersina* GRAY, 1847, and *Plesioniscia* FISCHER, 1884, is a junior synonym of *Morum* (*s. s.*) RÖDING, 1798. The name "*Onimusiro*" was first used by KIRA (1955) in a caption for a figure of "*Morum* (*Onimusiro*) *grande*." KIRA (1955; 1959) did not present a diagnosis nor did he designate a type species for "*Onimusiro*." The International Code of Zoological Nomenclature, however, requires a definite fixation of a type species for genus-group names proposed after 1930 (Art. 13b), and new names published after 1930 must be accompanied by a statement purporting to give characters differentiating the taxon (Art. 13, a, i).

Thus, "*Onimusiro*" was not properly proposed, and we have not found a validation of the name in the literature, unless HABE (1964, p. 64) inadvertently validated it as a replacement name when he noted that "*Onimusiro*" substitutes *Oniscidia* SWAINSON, which was stated to be a misspelling of *Oniscia* SOWERBY. If his statement constitutes a validation, *Onimusiro* would date from HABE, 1964; consequently it would be referable to the synonymy of *Cancellomorum* EMERSON & OLD, 1963: 18.

*Oniscia cancellata* G. B. SOWERBY, 1<sup>st</sup> of name, 1824, The Genera of Recent and fossil shells, *Oniscia* figs. 1 - 3 [western Pacific]. Type material presumed lost.

*Oniscia strombiformis* REEVE, 1842, Conch. system. 2: 210, plt. 253, fig. 1 [West Indies]. Holotype in the British Museum (Natural History), No. 1966723, *ex* H. Cuming collection. Provenance not stated in the original description, but it is cited from "Honduras" by REEVE (1849) and MELVILL (1919, p. 71). CLENCH & ABBOTT (1943, p. 5), in a review of the western Atlantic species of the genus, suggested that the type specimen may have been obtained by Cuming in the Philippine Islands. As a result of the present study, a specimen with definite locality data was obtained on loan through the kind offices of Dr. Leo G. Hertlein of the California Academy of Sciences. It was found washed up on the beach at Cartagena Bay, Colombia, by Dr. F. M. Anderson in 1915. The specimen is worn, but agrees well with the description of REEVE's taxon. It has a shorter spire and a less mature outer lip than the type specimen (compare Figures 1 and 2 with Figure 3 of Plate 12 in the present paper).

*Oniscia dennisoni* REEVE, 1842, Conch. system. 2: 212, plt. 253, figs. 5, 6 [western Atlantic]. Holotype in the British Museum (Natural History), No. 19601620. See Part I of the present paper.

*Oniscia exquisita* ADAMS & REEVE, 1850, in A. ADAMS, The zoology of the voyage of H. M. S. Samarang . . ., Mollusca p. 35, plt. 5, figs. 3a, 3b [western Pacific]. The depository of the holotype was not known to MELVILL (1919, p. 72) and is not known to us.

*Oniscia grandis* A. ADAMS, 1855, Proc. Zool. Soc. London for 1853, p. 185 [western Pacific]. Lectotype in the British Museum (Natural History), No. 1966726, figured by YEN (1942, plt. 17, fig. 104).

*Oniscia cithara* WATSON, 1881, Journ. Linn. Soc. Zool., 15: 266; 1886, Rpt. Sci. Res. Voy. H. M. S. Challenger, 15: 410, plt. 34, fig. 6 [western Pacific]. Holotype in the British Museum (Natural History), No. 1887.2.0.1262. The unique type specimen is not fully grown. Not "*Oniscia cithara*. *Buccinum Cythara* BROCCHI" G. B. SOWERBY, 1<sup>st</sup> of name, 1824, The Genera of Recent and fossil shells, *Oniscia* p. 2, fig. 5 [= *Buccinum cythara* BROCCHI, 1814,

Conch. foss. Subappennina . . ., p. 330], an extinct species of *Morum*.

*Oniscia macandrewi* G. B. SOWERBY, 3<sup>rd</sup> of name, 1889, Proc. Zool. Soc. London for 1888: 567, plt. 28, figs. 1, 2 [western Pacific]. Holotype in the Melvill-Tomlin collection, National Museum of Wales, Cardiff, U. K.

*Morum praeclarum* MELVILL, 1919, Proc. Malacol. Soc. London 13: 69, text fig. [? western Pacific]. Holotype in the Melvill-Tomlin collection, National Museum of Wales, Cardiff, U. K.

*Oniscidia bruuni* POWELL, 1958, Rec. Auckland Inst. Mus. 5: 80, plt. 11, fig. 5 [western Pacific]. Holotype in the Zoological Museum, Copenhagen, Denmark.

*Morum (Onimusiro) teramachii* KURODA & HABE, in T. HABE, Coloured illustr. shells Japan II, 1961, Appen. p. 15, plt. 20, fig. 3 [western Pacific]. Holotype in the National Science Museum, Tokyo, Japan. No. 38900.

*Morum (Onimusiro) uchiyamai* KURODA & HABE, in T. HABE, Coloured illustr. shells Japan II, 1961, Appen. p. 16, plt. 20, fig. 5 [western Pacific]. Holotype in personal collection of Prof. Kawamura, Tokyo, Japan.

*Morum (Cancellomorum) matthewsi* EMERSON, 1967, The Veliger 9: 290; plt. 39, figs. 2 - 4 [western Atlantic]. Holotype in the American Museum of Natural History, No. 129201.

*Morum (Cancellomorum) watsoni* DANCE & EMERSON, new name for *Oniscia cithara* WATSON, 1881, not *Oniscia cythara* (BROCCHI, 1814). Under the provisions of Articles 59b and 58 (9) of the International Code of Zoological Nomenclature WATSON's taxon is a secondary homonym and must be replaced (Art. 60b). *Vide supra: Oniscia cithara* WATSON, 1881.

"*Morum sobrinus* A. ADAMS" may be a manuscript name that is referable to one of the Recent cancellate species, although we have not found a citation to this taxon in the primary literature. This name appears in a recently published popular handbook. It is also on a label accompanying a specimen of *Morum macandrewi* (SOWERBY) that was recently received from Japan and is in the collection of the American Museum. It seems more likely, however, that "*Morum sobrinus*" is a *lapsus* for *Murex sobrinus* of ARTHUR ADAMS (1863, p. 370) from Japan.

(*Pulchroniscia*) GARRARD, 1961

Type species: *Pulchroniscia delecta* GARRARD, 1961, by M?

Fixation of the type species of "*Pulchroniscia delecta* gen. et sp. nov." by monotypy is open to question. The formula, "gen. n., sp. n.," was not acceptable for fixing generic type species after 1930 by the provisions of Art. 68(a) (i) of

the International Code of Zoological Nomenclature. This taxon is tentatively placed in the genus, in the absence of knowledge of the soft parts.

*Pulchroniscia delecta* GARRARD, 1961, Journ. Malacol. Soc. Austral. no. 5, p. 16, pl. 1, figs. 9a, 9b [western Pacific]. Holotype in the Australian Museum No. 63343. The description was based on a single specimen, and no further specimens have been found, *teste* T.A. Garrard (*in litt.*, April 1967).

### III. Annotated List of the Fossil Representatives of the Genus *Morum* RÖDING, 1798, reported from the New World

#### *Morum* (*sensu stricto*)

*Morum oniscus* (LINNAEUS), GABB, 1881, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, p. 357, [late] Pliocene, Moin Hill, Costa Rica. [Geological range: Pliocene to Recent].

*Morum floridana* [*sic*] TUCKER & WILSON, 1933, Bull. Amer. Paleont. 18 (66): 71; pl. 10, figs. 3-5, "Pliocene," Prairie Creek, Florida. The shell of this taxon is stated to differ from that of *M. oniscus* (LINNAEUS) in having a higher spire and by possessing more axial ribs.

*Morum tuberculatum* "SOWERBY" (REEVE), JORDAN, 1936, Contrib. Dept. Geol. Stanford Univ. 1: 114, Pleistocene, Magdalena Bay, Baja California, Mexico; PALMER & HERTLEIN, 1936, Bull. South. Calif. Acad. Sci. 35: 68, Pleistocene, Oaxaca, Mexico; HERTLEIN & STRONG, 1939, Proc. Calif. Acad. Sci. 33: 370, Pleistocene, Isla San Salvador, Galápagos Islands, Ecuador. [Geological range: Pleistocene to Recent].

(*Cancellomorum*) EMERSON &  
OLD, 1963

*Oniscia scotlandica* TRECHMANN, 1925, Geol. Mag. 62: 491, pl. 24, figs. 18a, 18b, Scotland Beds, Barbados; middle Eocene according to W.P. Woodring (*in litt.*, June 16, 1966).

*Morum* ("Oniscidia") species WOODRING, 1959, U.S. Geol. Surv. Prof. Paper 306-B: 202, 203, pl. 25, figs. 11, 17, mid-Eocene, Gatuncillo formation, Panama Canal Zone. [Record based on a small fragment].

*Morum caracoli* (ANDERSON, 1938), Geol. Soc. Amer. Spec. Papers, no. 16, p. 19, pl. 1, fig. 5, Eocene, Colombia, as "*Athleta* (*Volutospira*) *caracoli*." CLARK, in CLARK & DURHAM, 1946, Geol. Soc. Amer., Mem. 16: 35, pl. 21. According to WOODRING (1959, p. 203), ANDERSON's taxon ". . . is an earlier name for *M. corrugatum*, if not also for *M. chiraense*."

*Morum* (*Herculea*) *corrugatum* CLARK, in CLARK & DURHAM, 1946, Geol. Soc. Amer., Mem. 16: 34, pl. 21,

figs. 5, 21, late Eocene of Colombia (see remarks for *M. caracoli*).

*Morum* ("Oniscidia") cf. *M. antiquum* (BAYAN), WOODRING, 1959, U.S. Geol. Surv. Prof. Paper 306-B: 203, pl. 25, figs. 12, 13, late Eocene or early Oligocene, Bohio(?) formation, Gatun Lake area, Panama. WOODRING records an incomplete, strongly cancellate, low spired specimen, which apparently represents an unnamed species, and he compares it with BAYAN's taxon, a species described from Eocene deposits in Italy.

*Morum peruvianum* OLSSON, 1931, Bull. Amer. Paleont. 17 (63): 95, pl. 17, figs. 5, 7, late Eocene or early Oligocene of Peru. Stated to be related to *M. harpulum* (CONRAD).

*Morum chiraense* OLSSON, 1931, Bull. Amer. Paleont. 17, no. 63, p. 96, pl. 17, figs. 6, 8, late Eocene or early Oligocene of Peru (see remarks for *M. caracoli*).

*Oniscia harpula* CONRAD, 1847, Proc. Acad. Nat. Sci. Philadelphia 3: 288; 1848, Journ. Acad. Nat. Sci. Philadelphia, ser. 2, 1: 119, pl. 12, fig. 6, [Oligocene], vicinity of Vicksburg, Mississippi.

*Oniscia domingensis* SOWERBY, 1850, Quart. Journ. Geol. Sci. London 6, pt. 1, p. 47, pl. 10, fig. 3, "Santo Domingo," PILSBRY, 1922, Proc. Acad. Nat. Sci. Philadelphia 73: 363 [Miocene, Dominican Republic].

*Oniscia coxi* TRECHMANN, 1935, Geol. Mag. 72 (12): 543, pl. 21, fig. 17, Grand Bay Beds, "L. Miocene = Burdigalian (?) = Cercado or Baitoa beds of Haiti," Carriacou Islands, West Indies.

*Morum chipolanum* "DALL" MAURY, 1925, Brazil Serv. Geol. Mineral. Monogr. 4: 115, 617, pl. 4, fig. 4, early Miocene, [Chipola Formation], Florida; GARDNER, 1947, U.S. Geol. Surv. Prof. Paper 142-H: 538, pl. 54, fig. 18, as "*Morum chipolanum* (DALL, ms.) GARDNER, n. sp.," Chipola formation, Calhoun County, Florida.

*Morum* ("Oniscidia") cf. *M. chipolanum* MAURY, WOODRING, 1959, U.S. Geol. Surv. Prof. Paper 306-B: 203, early Miocene, Culebra formation, Gaillard Cut, Panama Canal Zone. WOODRING records a small, incomplete specimen, with strongly developed axial ribs and axial lamellae, that is reminiscent of *M. chipolanum*.

*Morum chipolanum tampanum* MANSFIELD, 1937, Florida Dept. Conserv., Geol. Bull. 15: 141, early Miocene, Tampa limestone, Florida; type specimen figured by DALL, 1915, U.S. Nat. Mus. Bull. 90, pl. 12, fig. 28, as "*Morum domingense* SOWERBY." Not SOWERBY, 1850.

*Morum harrisi* MAURY, 1925, Brazil Serv. Geol. Mineral., Monogr. 4: 115, pl. 4, fig. 14, early Miocene, Rio Pirabas, Pará, Brazil.

*Morum* (*Oniscidia*) *obrienae* OLSSON & PETIT, 1964, Bull. Amer. Paleont. 47 (212): 555, 556, pl. 80, figs. 8, 8a

(not "Pl. 83, figs. 8, 8a"), Pliocene, Caloosahatchee marl, Fort Denaud, Lee County, Florida.

*Morum macgintyi* [sic] MAXWELL SMITH, 1937, *Nautilus* 51 (2): 67, 68, pl. 6, fig. 12, Pliocene, Clewiston, Florida; OLSSON & PETT, 1964, *Bull. Amer. Paleont.* 47 (217): 556, 574, pl. 80, fig. 7 [holotype refigured; cited from "? Unit A"].

Tertiary representatives of *Morum* that are apparently referable to the subgenus *Cancellomorum* also are known from Europe, India, Indonesia, New Zealand, and Japan.

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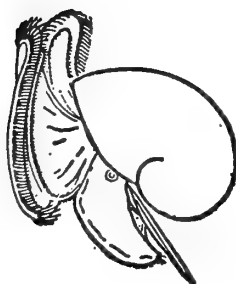
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# On the Identity of *Phos laevigatus* A. ADAMS, 1851

(Mollusca : Gastropoda)

BY

WILLIAM K. EMERSON

Department of Living Invertebrates, The American Museum of Natural History  
Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 13)

## INTRODUCTION

*Phos laevigatus* was briefly described by ARTHUR ADAMS (1851) on the basis of a single specimen which apparently was in the collection of Hugh Cuming. The specimen was stated to have been obtained at the Cape of Good Hope. As was the case for most of the numerous new taxa that were proposed by ARTHUR ADAMS, no illustrations were provided and the description was not very diagnostic. G. B. SOWERBY, 2<sup>ND</sup> (1859) subsequently figured a dorsal view of the type specimen and TRYON (1881) copied this figure. An illustration of an apertural view of the holotype is presented for the first time in the present paper (Plate 13, Figure 1). Both SOWERBY and TRYON repeated ADAMS' locality citation. Additional specimens apparently have not been referred to *Phos laevigatus* since the appearance of the original description of this taxon more than one hundred years ago.

As a result of the present study, evidence is presented to demonstrate that *Phos laevigatus* A. ADAMS (1851) actually occurs in the tropical eastern Pacific Ocean, where it is currently known as "*Phos*" *chelonina* DALL (1917), a taxon described from off the Galápagos Islands.

## DISCUSSION

The problem of the identity of these taxa first came to my attention when I received from Mrs. Carmen Angermeyer three specimens of "*Phos*" that she had collected in the Galápagos Islands. On examination, I found the two smaller specimens (Plate 13, Figure 5) to be referable to DALL's "*Phos*" *chelonina*, but the larger, obviously mature

specimen (Plate 13, Figure 7) appeared to be referable to "*Phos*" *laevigatus*, which had been reported from the Cape of Good Hope.

Through the kind offices of Mr. Norman Tebbel of the British Museum (Natural History) and Dr. Joseph Rosewater of the U. S. National Museum, I obtained from their respective institutions, a photograph of the apertural view of ADAMS' type and the loan of the type specimens of DALL's taxon. Our largest Galapagan specimen proved to be a live-taken example of "*Phos*" *laevigatus*, and our smaller Galapagan specimens were found to be fresh specimens of "*Phos*" *chelonina*, which was determined to be based on immature specimens that are referable to "*Phos*" *laevigatus*. The availability, however, of ADAMS' name for the Galapagan species would appear to be challenged by the Fifty Year Rule. Under Article 23 (b) of the International Code of Zoological Nomenclature, "A name that has remained unused as a senior synonym in the primary literature for more than fifty years is to be considered a forgotten name (*nomen oblitum*).<sup>1</sup>" The code requires that, if such a name is discovered after 1960, it should be referred to the Commission to be placed on either the Official Index of Rejected Names or the Official List of Preserved Names. Under the peculiar circumstances of the present case, I prefer to consider ADAMS' *laevigatus* an earlier valid name for the nominal species, *Phos chelonina* DALL. ADAMS' taxon would be without question the first available name for this species, if the Rule of Priority were followed.<sup>1</sup>

<sup>1</sup> At the time of this writing, the "Fifty-Year Rule" (Article 23b) was under suspension, and this matter was to be considered at the next meeting of the International Commission on Zoological Nomenclature (Bull. Zool. Nomencl., vol. 23, p. 260, 1966).

## SYSTEMATIC TREATMENT

## BUCCINIDAE

*Metaphos* OLSSON, 1964

**Type species:** *Phos chelonia* DALL, 1917 [= *Metaphos laevigatus* (A. ADAMS, 1851)], by O. D. Recent, Galápagos Islands, in 11 to 40 fathoms.

Other referred species are: *Metaphos cocosensis* (DALL, 1896), Gulf of California and off the Tres Mariás Islands, Mexico (PARKER, 1964), and off Cocos Island in the Gulf of Panama (Recent); *M. pacificus* OLSSON, 1964, *M. scillus* OLSSON, 1964, and *M. calathus* OLSSON, 1964, all from the Esmeraldas formation in northwestern Ecuador (early Pliocene?). *Metaphos cocosensis* is questionably reported by PILSBRY & OLSSON (1941) from the Jama formation in western Ecuador (Pliocene), and it is recorded from Pleistocene deposits on Albemarle Island of the Galápagos Islands by DALL & OCHSNER (1928).

**Remarks:** As pointed out by OLSSON (1964), none of the nearly 50 *Phos*-like species that are known from the Cenozoic faunas of the New World is referable to the genus *Phos* of MONTFORT, 1810. The type of *Phos* (*sensu stricto*) is *Murex senticosus* LINNAEUS, 1758, a Recent species occurring in the Indo-Pacific faunal province.

The shells of the species assigned to *Metaphos* resemble those of the genus *Cymatophos* PILSBRY & OLSSON (1941), but they differ notably by the possession of a larger and more strongly sculptured nucleus. The type species of *Cymatophos* is *Cymatophos galeris* PILSBRY & OLSSON, 1941, a Pliocene species from the Jama formation in western Ecuador.

*Metaphos laevigatus* (A. ADAMS, 1851)

(Plate 13)

*Phos laevigatus* A. ADAMS, 1851, p. 155, "Hab. Promontorium Bonae Spei." SOWERBY, 1859, *Phos* no. 10, pl. 221, fig. 6 [dorsal view of type], Cape of Good Hope. TRYON, 1881, p. 217, pl. 83, fig. 499 [copy of SOWERBY's figure].

*Phos chelonia* DALL, 1917, p. 578. "Dredged at the Galápagos Islands in 40 fathoms." STRONG & LOWE, 1936, p. 310, pl. 22, fig. 3 [holotype].

**Type localities:** of *laevigatus*, not Cape of Good Hope, here corrected to the Galápagos Islands; of *chelonia*, U. S. Fish Commission Station 2813, 01° 21' 00" S, 89° 40' 15" W, off the Galápagos Islands, in 40 fathoms, coarse sand.

**Type depositories:** of *laevigatus*, British Museum (Natural History), holotype no. 1966128, here figured, Plate 13, Figure 1; of *chelonia*, U. S. National Museum, holotype no. 194961, here figured, Plate 13, Figures 3, 4, and paratypes no. 637989, 12 specimens, including 5 fragmental specimens.

**Descriptions:** As was pointed out by STRONG & LOWE (1936, p. 308) in their review of the "West American species of the genus *Phos*," the characters of the nuclear whorls, presence or absence of a columellar keel, and dentition of the outer lip are specific characters, whereas the color, number of ribs, and details of sculpture are more variable characters. The present study serves to corroborate their findings.

The holotype of *laevigatus* is not well preserved, lacking the nuclear whorls, and is approximately 38 mm in length (Plate 13, Figure 1). Our largest Galapagan specimen is a well-preserved, live-taken individual with 5½ post-nuc-

## Explanation of Plate 13

*Metaphos laevigatus* (A. ADAMS)

Figure 1: Holotype of *Phos laevigatus* A. ADAMS, in British Museum (Natural History), No. 1966128; about x 2.

Figure 2: Copy of figure of holotype of *Phos laevigatus* A. ADAMS after SOWERBY, 1859, pl. 221, fig. 6; x 2.

Figures 3, 4: Holotype of *Phos chelonia* DALL, in U. S. National Museum, No. 194961; x 2. Figure 3, photographed with incandescent light, Figure 4 photographed with ultraviolet light.

Figure 5: Juvenile specimen of *Metaphos laevigatus* (A. ADAMS), left Figure photographed with incandescent light, right Figure photographed with ultraviolet light, dredged off Barrington Island, Galápagos Islands, in 14 fathoms, together with the specimen illustrated below as Figure 7, by the Angermeyers, American Museum

of Natural History No. 135503; x 2.

Figure 6: Juvenile specimen, paratype of *Phos chelonia* DALL, left Figure photographed with incandescent light, right Figure photographed with ultraviolet light, U. S. National Museum No. 637989; x 4.

Figures 7, 8: Mature specimens of *Metaphos laevigatus* (A. ADAMS); x 2. Figure 7, dredged in same haul with the specimen illustrated above as Figure 5, American Museum of Natural History, No. 135504. Figure 8, dredged in Academy Bay, Indefatigable Island, in 24.5 fathoms, deposited in the collection of Mrs. DeRoy. Early whorls of the specimen clearly show the characters of juvenile paratypic specimens of *Phos chelonia* DALL, cf. Figures 6 and 8.



Figure 1



Figure 2

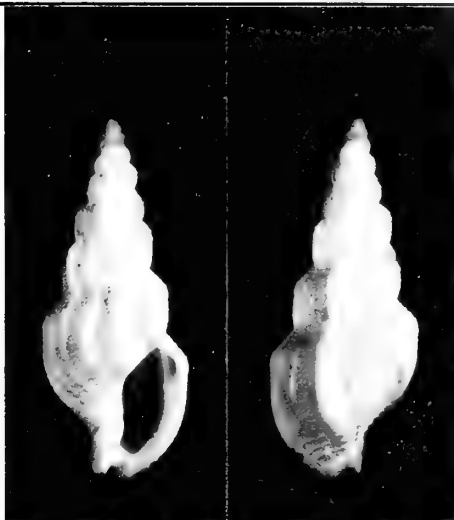


Figure 3

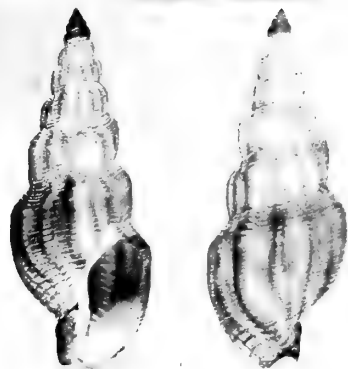


Figure 4



Figure 5



Figure 6

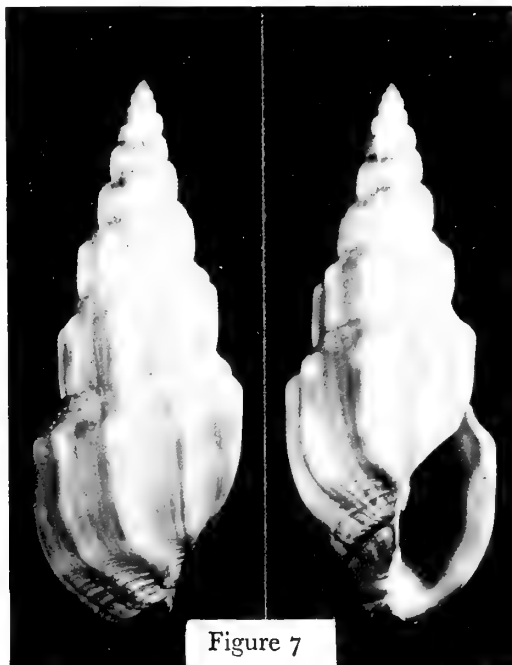


Figure 7

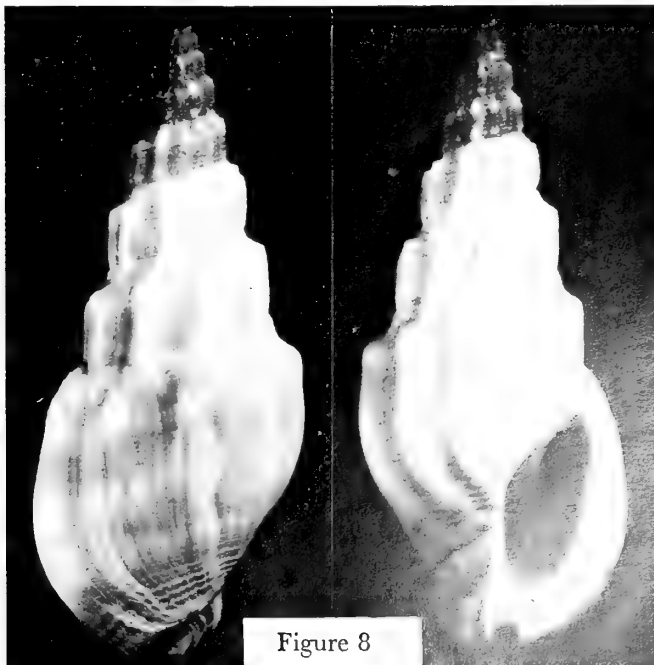


Figure 8



lear and  $3\frac{1}{2}$  nuclear whorls and the shell measures 36.4 mm in length (Plate 13, Figure 7). The nuclear whorls of the latter specimen are spirally sulcate with weak axial riblets. The first three post-nuclear whorls have strong axial ribs that are crossed by fine spiral lamellae; the remaining whorls have fewer but coarser axial ribs and finer and more numerous spiral riblets. The base of the body whorl has low, spiral ridges. In the last two whorls, the axial ribs terminate below the sutures and the intervening sutural regions have spiral riblets. The color of the shell is basically whitish buff, but is tinged with purplish brown on the body whorl, on the anterior canal and the basal spiral riblets. Weakly mottled, rusty brown stains occur in the sutural areas of the early whorls. The aperture is whitish within with a tinge of purple. Operculum is semi-crescentic in outline and possesses an apical nucleus.

All the type specimens of *chelon* are dead-collected, rather bleached specimens, with only a suggestion of the original color patterns. Photographed under ultraviolet light (cf. Figures 3, 4, 6), the fluorescent patterns of the pigments remaining on the surface of the type specimens are evident, but these patterns are reversed, *i. e.* the white areas appear as dark areas and the dark areas appear as white areas. The holotype, the largest specimen in the type lot, is a complete specimen with  $4\frac{1}{2}$  post-nuclear whorls and  $3\frac{1}{2}$  nuclear whorls and measures only 24.5 mm in length (Plate 13, Figures 3, 4). The sculpture of the holotype of *chelon*, which possesses one less whorl than our largest Galapagan specimen, agrees in all details with the ornamentation of each corresponding whorl of the holotype of *laevigatus* and our Galapagan specimens (cf. Figures 3, 4 with Figures 1, 7, 8). The body whorl of *chelon* has the ridge of the siphonal fasciole tinged with purple as does the holotype of *laevigatus* and our largest Galapagan specimen (cf. Figure 3 with Figures 7, 8). The brownish stains that occur in the sutural regions in the well-preserved Galapagan specimens, although not preserved in the holotype of *chelon*, are preserved in some of DALL's paratypes.

Non-typological specimens examined, all from off the Galápagos Islands:

Off Barrington Island [Isla Santa Fe], in 13 to 20 fathoms, Angermeyer leg., 1 specimen, 27.6 mm in length, Calif. Acad. Sci. no. 39280.

Off Barrington Island, in about 14 fathoms, 3 live-collected specimens from the gray sand, in the same dredge haul, Angermeyer leg., February 1965, 1 specimen, 36.4

mm in length (Plate 13, Figure 7), Amer. Mus. Nat. Hist. no. 135503; 1 specimen, 15.3 mm in length (Plate 13, Figure 5), Amer. Mus. Nat. Hist. no. 135504; 1 specimen, 16.2 mm in length, Amer. Mus. Nat. Hist. no. 135502.

Off Jervis Island [Isla Rábida], in about 11 fathoms, DeRoy leg., April 1966, 2 dead specimens, 26.6 and 14.1 mm in length, respectively, Amer. Mus. Nat. Hist. no. 135501.

Academy Bay, Indefatigable Island [Isla Santa Cruz], in 24.5 fathoms, sand, DeRoy leg., December 1966, 1 live-collected specimen, 42.6 mm in length (Plate 13, Figure 8), DeRoy Collection.

Near the Galápagos Islands,  $0^{\circ} 21' 30''$  N,  $89^{\circ} 37' 45''$  W, in 20 fathoms, coral sand, U. S. Fish Commission Steamer *Albatross* Station 2812, April 1887, 2 dead specimens, 15.6 and 12.9 mm in length, respectively, U. S. Natl. Mus. no. 206704.

After the text for this manuscript was completed, we received from Mrs. Jacqueline DeRoy three additional specimens, including a large, fully mature, extremely well-preserved specimen that was dredged alive from Academy Bay, Indefatigable Island (see Plate 13, Figure 8). In this specimen, the largest I have seen, the early whorls preserve the conchological characters and the color pattern that are typical for juvenile paratypic specimens of DALL's taxon (cf. Plate 13, Figures 6 and 8). On the other hand, the later whorls of Mrs. DeRoy's large specimen are typical for the characters of ADAMS' holotype of *Phos laevigatus* (cf. Figures 1, 2 with Figure 8).

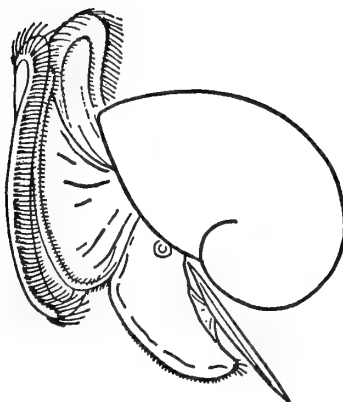
On the basis of the material now available for study, I must conclude that DALL's *chelon* was based on juvenile specimens which are referable to ADAMS' *laevigatus*. Therefore, *Phos chelon* DALL, 1917, is a junior subjective synonym of *Phos laevigatus* A. ADAMS, 1851, which is in fact a constituent of the Panamic faunal province.

## ACKNOWLEDGMENTS

In addition to Mesdames Carmen Angermeyer and Jacqueline DeRoy of Academy Bay, Isla Santa Cruz, Galápagos Islands, I am indebted to the following individuals for courtesies of various kinds: Mr. Norman Tebble of the British Museum (Natural History); Dr. Joseph Rosewater of the U. S. National Museum; Dr. Leo George Hertlein of the California Academy of Sciences; Dr. Edward C. Wilson of the San Diego Natural History Museum; and Mr. William E. Old, Jr. and Miss Rae Weinstein of the American Museum of Natural History.

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# Studies on East Australian Cowries

BY

MARIA SCHILDER

AND

FRANZ ALFRED SCHILDER

University of Halle, German Democratic Republic

DURING THESE LAST YEARS we have examined 8300 cowrie shells coming from 170 localities in the area between Cooktown, Kenn Reef (SCHILDER, 1966) and Sydney: this multitude of cowries with exact locality data allows a special study on the cowrie fauna of East Australia in the true sense, as we have excluded the Torres Straits, southern New South Wales, and the Lord Howe Islands.

The investigated area comprises the areas QUE 47q, 47c, 47b and the northern half of 47s in SCHILDER, 1965, page 175.

We are much indebted to the following malacologists some of whom presented or lent us large series of cowries collected in restricted localities: W. O. Cernohorsky, Vatu-koula (Fiji), Miss D. Constantine, Cowes (Victoria), \*C. Coucom, Yeppoon (Queensland), R. J. Griffiths, Port Macquarie (New South Wales), Mrs. E. D. Harton, Coff's Harbour (N. S. W.), \*W. Hart-Smith, North Sydney (N. S. W.), \*G. Houston, Mackay (Qld.), \*W. Krause, Avoca Beach (N. S. W.), \*Mrs. M. Lee, Maroochydore (Qld.), \*Mrs. K. M. Matcott, Dromana (Victoria), \*A. Schelechoff, Brisbane (Qld.), S. R. Shadlow, Mermaid Beach (Qld.), R. Summers, Petaluma (California), \*Mrs. E. Tautorat, Hayman Island (Qld.), \*K. Uetz, Vienna (Austria). Collectors distinguished with an asterisk (\*) have supplied us with the ten local sets each exceeding 250 shells which will be treated in Table 3.

## Total Frequency of Species

Table 1 comprises the following columns:

- 1 = total number of examined specimens coming from East Australia;
- 2 = number of specimens represented in 10 large sets from restricted localities, each set including at least 250 shells;
- 3 = name of genus and species (or prospectus) according to SCHILDER, 1967<sup>1</sup>;

<sup>1</sup> The generic name *Cribraria* JOUSSEAUME, 1884 is preoccupied by

4 = column 1 (East Australia) expressed in per cent of the total 8300;

5 = column 2 (10 large sets) expressed in per cent of the total 5936.

In columns indicating the percentage of shells, *i. e.* in the columns 4 and 5 of Table 1 and in all columns of Tables 3 to 6

the figure 0 indicates "less than  $\frac{1}{2}\%$ ,"

the sign - indicates total absence, and

figures printed in ***boldface italics*** indicate "characteristic species," *i. e.* the most common species the total number of which just exceeds 50% of the collected specimens.

The six "characteristic species," *i. e.* the most frequent species the total number of which just exceeds 50% of all East Australian cowries collected, are identical with those represented in the total of the 10 largest sets, and even the percentage of specimens is very similar: their percentage among the total of 8300 shells (67 species) and among the 10 sets containing 5936 shells (63 species) is illustrated in Table 2.

Though this conformity may be explained by the great influence of the 10 sets over the total (of which the sets constitute 72%), the Table 2 shows that the sum of the 10 sets can be considered as a good representative of the East Australian cowrie fauna.

## Frequency in Different Localities

The 10 large sets each exceeding 250 specimens seem to represent random samples from restricted localities. The

*Cribraria* GMELIN, 1792 and PERSOON, 1794; though the latter genus is now considered to belong to plants (Myxomycetes), its members often have been treated as animals ("Mycetozoa") before 1884 so that STRAND, 1929 (Acta Univ. Latviensis 20: 8) was correct to rename the cowrie genus by the name *Cribrarula* (see International Rules of Zoological Nomenclature, 1958, art. 2 b).

Table 1

1	2	3	4	5
<i>Mauritia</i>				
3	2	<i>mappa</i> (LINNAEUS, 1758)	0	0
275	230	<i>eglantina</i> (DUCLOS, 1833)	3	4
242	115	<i>arabica</i> (LINNAEUS, 1758)	3	2
4	3	<i>mauritiana</i> (LINNAEUS, 1758)	0	0
6	2	<i>scurra</i> (GMELIN, 1791)	0	0
<i>Talparia</i>				
20	19	<i>talpa</i> (LINNAEUS, 1758)	0	0
<i>Cypraea</i>				
13	12	<i>tigris</i> LINNAEUS, 1758	0	0
<i>Lyncina</i>				
11	8	<i>argus</i> (LINNAEUS, 1758)	0	0
224	173	<i>lynx</i> (LINNAEUS, 1758)	3	3
278	216	<i>vitellus</i> (LINNAEUS, 1758)	3	4
197	164	<i>carneola</i> (LINNAEUS, 1758)	2	3
<i>Chelycypraca</i>				
1	—	<i>testudinaria</i> (LINNAEUS, 1758)	0	—
<i>Luria</i>				
81	72	<i>isabella</i> (LINNAEUS, 1758)	1	1
<i>Pustularia</i>				
1	—	<i>mariae</i> SCHILDER, 1927	0	—
20	20	<i>globulus</i> (LINNAEUS, 1758)	0	0
30	29	<i>margarita</i> (DILLWYN, 1817)	0	1
81	78	<i>cicercula</i> (LINNAEUS, 1758)	1	1
35	1	<i>bistrinotata</i> SCHILDER & SCHILDER, 1937	0	0
<i>Monetaria</i>				
385	281	<i>annulus</i> (LINNAEUS, 1758)	5	5
214	200	<i>moneta</i> (LINNAEUS, 1758)	3	4
<i>Erosaria</i>				
242	199	<i>labrolineata</i> (GASKOIN, 1849)	3	4
15	11	<i>tomlini</i> SCHILDER, 1930	0	0
13	8	<i>helvola</i> (LINNAEUS, 1758)	0	0
346	270	<i>caputserpentis</i> (LINNAEUS, 1758)	4	5
7	4	<i>poraria</i> (LINNAEUS, 1758)	0	0
568	444	<i>erosa</i> (LINNAEUS, 1758)	7	8
2	2	<i>miliaris</i> (GMELIN, 1791)	0	0
12	7	<i>eburnea</i> (BARNES, 1824)	0	0
<i>Staphylaea</i>				
173	147	<i>staphylaea</i> (LINNAEUS, 1758)	2	3
78	71	<i>limacina</i> (LAMARCK, 1810)	1	1
<i>Nuclearia</i>				
83	73	<i>nucleus</i> (LINNAEUS, 1758)	1	1
<i>Schilderia</i>				
4	4	<i>moretonensis</i> SCHILDER, 1965	0	0
1	1	<i>queenslandica</i> SCHILDER, 1966	0	0
<i>Umbilia</i>				
5	1	<i>hesitata</i> (IREDALE, 1916)	0	0
<i>Erronea</i>				
25	6	<i>walkeri</i> (SOWERBY, 1832)	0	0
5	—	<i>pyriformis</i> (GRAY, 1824)	0	—
10	10	<i>coucomi</i> SCHILDER, 1964	0	0
1117	658	<i>xanthodon</i> (SOWERBY, 1832)	13	11
161	104	<i>subviridis</i> (REEVE, 1835)	2	2

1	2	3	4	5
<i>Erronea</i> (continued)				
1	—	<i>ovum</i> (GMELIN, 1791)	0	—
1157	747	<i>errones</i> (LINNAEUS, 1758)	14	12
64	29	<i>cylindrica</i> (BORN, 1778)	1	0
251	208	<i>caurica</i> (LINNAEUS, 1758)	3	4
218	137	<i>listeri</i> (GRAY, 1824)	3	2
<i>Notadusta</i>				
16	4	<i>punctata</i> (LINNAEUS, 1771)	0	0
2	1	<i>martini</i> (SCHEPMAN, 1907)	0	0
1	1	<i>hartsmithi</i> SCHILDER, 1967	0	0
<i>Palmadusta</i>				
57	35	<i>asellus</i> (LINNAEUS, 1758)	1	1
195	166	<i>clandestina</i> (LINNAEUS, 1767)	2	3
6	1	<i>sauleae</i> (GASKOIN, 1843)	0	0
2	1	<i>contaminata</i> (SOWERBY, 1832)	0	0
47	34	<i>humphreysii</i> (GRAY, 1825)	1	1
3	2	<i>ziczac</i> (LINNAEUS, 1758)	0	0
<i>Purpuradusta</i>				
727	534	<i>gracilis</i> (GASKOIN, 1849)	9	9
28	24	<i>hammondae</i> (IREDALE, 1939)	0	0
29	17	<i>minoridens</i> (MELVILL, 1901)	0	0
8	3	<i>microdon</i> (GRAY, 1828)	0	0
<i>Blasicrura</i>				
52	27	<i>quadrimaculata</i> (GRAY, 1824)	1	0
138	128	<i>pallidula</i> (GASKOIN, 1849)	2	2
25	19	<i>teres</i> (GMELIN, 1791)	0	0
<i>Bistolida</i>				
31	12	<i>kieneri</i> (HIDALGO, 1906)	0	0
64	45	<i>hirundo</i> (LINNAEUS, 1758)	1	1
5	2	<i>ursellus</i> (GMELIN, 1791)	0	0
144	90	<i>stolida</i> (LINNAEUS, 1758)	2	2
<i>Ovatipsa</i>				
6	4	<i>chinensis</i> (GMELIN, 1791)	0	0
<i>Cribrarula</i>				
32	19	<i>cribraria</i> (LINNAEUS, 1758)	0	0
3	1	<i>catholicorum</i> SCHILDER & SCHILDER, 1938	0	0

Table 2

most frequent species	total	10 sets
<i>Erronea</i>		
<i>errones</i> (LINNAEUS, 1758)	14%	12%
<i>xanthodon</i> (SOWERBY, 1832)	13%	11%
<i>Purpuradusta</i>		
<i>gracilis</i> (GASKOIN, 1849)	9%	9%
<i>Erosaria</i>		
<i>erosa</i> (LINNAEUS, 1758)	7%	8%
<i>Monetaria</i>		
<i>annulus</i> (LINNAEUS, 1758)	5%	5%
<i>Erosaria</i>		
<i>caputserpentis</i> (LINNAEUS, 1758)	4%	5%
sum of six species	52%	50%

localities have been arranged from North to South and are designated by the letters Q to Z as follows:

Q = Holborn Island (*leg.* Coucom, 1965): 528 shells;

R = Hayman Island (*leg.* Uetz, 1959 and Tautorat, 1963): 731 shells;

S = Penrith Island (*leg.* Houston, 1962): 472 shells (see SCHILDER & HOUSTON, 1964);

T = Middle Island (*leg.* Coucom, 1964 and 1965): 399 shells;

U = Humpy Island (*leg.* Coucom, 1963 and 1964): 664 shells;

V = One Tree Island (*leg.* Coucom, 1966): 1155 shells (see COUCOM & SCHILDER, 1967);

W = Maroochydore (*leg.* Lee, 1963): 453 shells;

X = Mooloolaba (*leg.* Matcott, 1963): 349 shells;

Y = Moreton Bay (*leg.* Schelechoff, mostly 1964): 930 shells;

Z = Avoca Beach (*leg.* Krause, 1962-1966) and Sydney area (*leg.* Hart-Smith, 1966): 255 shells.

The locality Q is situated North off Bowen; R is the northern border of the Whitsunday Group North of Mackay, S is its southern border; T and U are in the Keppel Bay off Yeppoon rather close to the coast (both are reefs bordering the Great Keppel Island in the North and the South, only 10 km apart), whereas V is 70 km off Cape Capricorn in the Barrier Reef; W and X represent practically the same beach South-East of Gympie; Y refers chiefly to the West coast of Stradbroke Island; Z comprises several beaches North of Sydney from Norah Heads to Port Jackson.

Table 3 shows the similarities and the differences be-

Table 3

species	Q	R	S	T	U	V	W	X	Y	Z
<i>Mauritia</i>										
<i>eglantina</i> (DUCLOS, 1833)	3	12	12	2	2	4	-	1	0	-
<i>arabica</i> (LINNAEUS, 1758)	0	1	-	4	3	5	1	1	1	1
<i>Lycina</i>										
<i>lynx</i> (LINNAEUS, 1758)	1	12	10	-	-	3	-	0	0	0
<i>vitellus</i> (LINNAEUS, 1758)	2	10	4	-	-	5	1	1	0	17
<i>carneola</i> (LINNAEUS, 1758)	9	1	0	-	-	7	1	1	1	1
<i>Luria</i>										
<i>isabella</i> (LINNAEUS, 1758)	6	3	-	-	0	1	-	-	0	-
<i>Pustularia</i>										
<i>margarita</i> (DILLWYN, 1817)	5	1	-	-	-	-	-	-	-	-
<i>cicercula</i> (LINNAEUS, 1758)	8	4	-	-	0	0	-	-	-	-
<i>Monetaria</i>										
<i>annulus</i> (LINNAEUS, 1758)	1	9	9	2	-	8	2	1	5	4
<i>moneta</i> (LINNAEUS, 1758)	0	0	7	-	-	7	2	4	4	7
<i>Erosaria</i>										
<i>labrolineata</i> (GASKOIN, 1849)	11	1	-	-	0	4	4	-	6	5
<i>caputserpentis</i> (LINNAEUS, 1758)	0	1	5	0	-	7	9	7	3	29
<i>erosa</i> (LINNAEUS, 1758)	6	8	10	2	4	7	6	5	12	16
<i>Staphylaea</i>										
<i>staphylaea</i> (LINNAEUS, 1758)	0	1	-	-	0	2	3	4	10	-
<i>limacina</i> (LAMARCK, 1810)	0	1	-	-	-	0	0	0	6	-
<i>Nuclearia</i>										
<i>nucleus</i> (LINNAEUS, 1758)	11	1	-	-	-	1	-	-	0	-
<i>Erronea</i>										
<i>xanthodon</i> (SOWERBY, 1832)	-	-	-	34	45	0	21	19	5	3
<i>subviridis</i> (REEVE, 1835)	-	1	-	1	6	-	1	1	5	1
<i>errones</i> (LINNAEUS, 1758)	5	11	26	40	27	8	5	2	6	1
<i>caurica</i> (LINNAEUS, 1758)	3	4	4	1	4	7	1	0	2	2
<i>listeri</i> (GRAY, 1824)	0	0	0	-	-	9	2	3	1	1
<i>Palmadusta</i>										
<i>clandestina</i> (LINNAEUS, 1767)	0	1	5	-	0	3	6	5	3	6
<i>humphreysii</i> (GRAY, 1825)	-	1	-	-	-	0	4	2	0	0
<i>Purpuradusta</i>										
<i>gracilis</i> (GASKOIN, 1849)	5	2	6	13	7	0	21	31	16	4
<i>Blasicrura</i>										
<i>quadrinaculata</i> (GRAY, 1824)	4	1	-	-	-	-	-	-	-	-
<i>pallidula</i> (GASKOIN, 1849)	6	3	0	-	-	6	-	-	-	-
<i>Bistolida</i>										
<i>stolida</i> (LINNAEUS, 1758)	2	1	-	1	1	0	7	9	-	-

tween the cowrie faunas collected at these 10 localities Q to Z. The figures indicate the percentage of species in each set. To facilitate comparison of the sets, the number of species has been restricted to 27 so that all rare species not exceeding 3% in any set have been omitted; but in the recorded species all data have been indicated even if the figures do not reach 4%; of course, the sums of these 10 columns never equal 100%. The figures for the "characteristic species" have been printed in boldface italics.

The figures entered in Table 3 seem to be rather haphazard as in most sets different cowries are the most frequent species. However, there are some cases of surprising regional regularity: thus, for instance, some species (*Mauritia arabica*, *Monetaria annulus*, *Erosaria erosa*, *Erronea caurica*) seem to be equally distributed in East Australia; other species (*M. eglantina*, *Lyncina lynx*, *Pustularia margarita* + *cicercula*, *Nuclearia nucleus*, *Erronea erronea*, *Blasicrura quadrimaculata*) occur chiefly in the northern localities, two species (*Erronea xanthodon*, *Purpuradusta gracilis*) prefer the central area, while other species (*Erosaria caputserpentis*, *Staphylaea staphylaea*, *S. limacina*) become more frequent in the South; *Lyncina vitellus* and *Erosaria labrolineata* could be classified as bicentric. However, these conclusions obtained from 10 populations only seem to be premature.

At any rate, there is some similarity among adjacent localities; in T and U *Erronea xanthodon* and *E. erronea* are prevalent, in W and X *Purpuradusta gracilis* and *E. xanthodon*, and even in R and S *E. erronea*, *Mauritia eglantina*, *Lyncina lynx*.

The southernmost area Z with predominance of *Erosaria caputserpentis* (race *caputanguis* PHILIPPI), *Lyncina vitellus* and *E. erosa* (race *pulchella* COEN) seems to be very different from the other East Australian areas: the cowrie fauna is poor, as the other tropical species become rare and the South Australian species usually do not extend as far as the Sydney area; besides, we have observed that an unusually large percentage of beach shells is not fully grown so that unfavorable conditions may cause the premature death of the animals.

### Frequency in Split Populations

The significance of the local differences illustrated by Table 3 may be checked by splitting some sets into two natural halves:

The set U (Humpy Island) is composed of two collections made in two subsequent years: 1963 (292 mostly fresh shells) and 1964 (372 mostly beach shells). The percentage of specimens collected in 1963 vs. those collected in 1964 (1963 : 1964) is illustrated in Table 4:

The figures exceeding 3% are very similar in both years, and the total absence of rare species in one year is only accidental; the 3 most frequent species are identical.

Table 4

U [Humpy Island]	
<i>Mauritia</i>	
<i>eglantina</i> (DUCLOS, 1833)	3 : 1
<i>arabica</i> (LINNAEUS, 1758)	4 : 2
<i>Luria</i>	
<i>isabella</i> (LINNAEUS, 1758)	0 : -
<i>Pustularia</i>	
<i>cicercula</i> (LINNAEUS, 1758)	- : 0
<i>bistrinotata</i> SCHILDER & SCHILDER, 1937	0 : -
<i>Erosaria</i>	
<i>labrolineata</i> (GASKOIN, 1849)	0 : -
<i>erosa</i> (LINNAEUS, 1758)	5 : 4
<i>Staphylaea</i>	
<i>staphylaea</i> (LINNAEUS, 1758)	- : 0
<i>Erronea</i>	
<i>xanthodon</i> (SOWERBY, 1832)	46 : 45
<i>subviridis</i> (REEVE, 1835)	5 : 7
<i>errones</i> (LINNAEUS, 1758)	26 : 27
<i>cylindrica</i> (BORN, 1778)	- : 0
<i>caurica</i> (LINNAEUS, 1758)	4 : 4
<i>Palmadusta</i>	
<i>clandestina</i> (LINNAEUS, 1767)	- : 0
<i>Purpuradusta</i>	
<i>gracilis</i> (GASKOIN, 1849)	6 : 8
<i>Bistolida</i>	
<i>hirundo</i> (LINNAEUS, 1758)	0 : -
<i>stolida</i> (LINNAEUS, 1758)	- : 1
<i>Cribrarula</i>	
<i>cribraria</i> (LINNAEUS, 1758)	- : 0

Both collections practically correspond each to the other.

The figures of collecting set T (Middle Island) in 1964 (295 shells) and in 1965 (104 shells) are illustrated in Table 5 in the same way:

Table 5

T [Middle Island]	
<i>Mauritia</i>	
<i>eglantina</i> (DUCLOS, 1833)	2 : -
<i>arabica</i> (LINNAEUS, 1758)	6 : -
<i>Monetaria</i>	
<i>annulus</i> (LINNAEUS, 1758)	1 : 2
<i>Erosaria</i>	
<i>caputserpentis</i> (LINNAEUS, 1758)	- : 1
<i>erosa</i> (LINNAEUS, 1758)	2 : 2
<i>Erronea</i>	
<i>xanthodon</i> (SOWERBY, 1832)	34 : 35
<i>subviridis</i> (REEVE, 1835)	- : 3
<i>errones</i> (LINNAEUS, 1758)	44 : 32
<i>caurica</i> (LINNAEUS, 1758)	1 : -
<i>Purpuradusta</i>	
<i>gracilis</i> (GASKOIN, 1849)	10 : 22
<i>Bistolida</i>	
<i>stolida</i> (LINNAEUS, 1758)	- : 3

Probably on account of the rather small number of shells collected in 1965, there is a less evident correspondence, as even the most common species is different (*Erronea erronea* : *E. xanthodon*), and *Mauritia arabica*, represented by 6% in 1964, was totally absent in 1965, while *E. subviridis* and *Bistolida stolid*a were represented by 3% in 1965 only.

Set V (One Tree Island) is composed of two parts, both collected in August 1966; we received 648 fine shells, mostly collected alive, and 507 badly worn beach specimens. As emphasized in a previous paper (COUCOM & SCHILDER, 1967) these faunas are very different (see Table 6: the first figure indicates per cent of the fresh specimens, the second figure those of the beach shells).

Here not a single species is "characteristic" in both parts: all species which must be classified as characteristic among the fresh shells are less frequent to rare among the beach shells, and *vice versa*, and even one characteristic beach shell (*Erosaria labrolineata*) is totally absent from among the fresh specimens. These numerical differences point to great ecological differences between the habitat of the live taken specimens and that of the dead shells washed ashore.

## Discussion of Frequency

The total frequency of East Australian cowries indicated by Table 1 can be regarded as genuine to a certain extent, though intensive trawling in deep waters may prove some very rare species to be less uncommon.

However, the frequency of species in each set cannot be taken for granted as genuine though in some sets it may be so, especially in sets composed of beach shells only (U 1964, W, X, Z). In other cases the percentage of species may be greatly influenced by the accidental conditions of the area searched by the collector. For investigations on Penrith Island (SCHILDER & HOUSTON, 1964) and on One Tree Island (COUCOM & SCHILDER, 1967) have shown that each cowrie species prefers certain tidal zones or even restricted places on the shore, and it is mere chance from which place the collector gets his set of living cowries, whereas dead shells washed ashore come from various zones and thus seem to represent the average fauna in a better way.

These facts confirm the studies on populations of living and fossil cowries published 25 years ago (SCHILDER, 1942).

## The Size of the Shells

The length of cowrie shells is a character influenced by individual, sexual, ecological, and geographical factors; the average length of specimens composing a local popu-

Table 6

	V [One Tree Island]	
<i>Mauritia</i>		
<i>eglantina</i> (DUCLOS, 1833)	2 :	7
<i>arabica</i> (LINNAEUS, 1758)	2 :	7
<i>Talparia</i>		
<i>talpa</i> (LINNAEUS, 1758)	- :	1
<i>Cypraca</i>		
<i>tigris</i> LINNAEUS, 1758	0 :	-
<i>Lyncina</i>		
<i>lynx</i> (LINNAEUS, 1758)	3 :	2
<i>vitellus</i> (LINNAEUS, 1758)	4 :	7
<i>carneola</i> (LINNAEUS, 1758)	3 :	12
<i>Luria</i>		
<i>isabella</i> (LINNAEUS, 1758)	- :	3
<i>Pustularia</i>		
<i>cicercula</i> (LINNAEUS, 1758)	- :	0
<i>Monetaria</i>		
<i>annulus</i> (LINNAEUS, 1758)	12 :	2
<i>moneta</i> (LINNAEUS, 1758)	12 :	1
<i>Erosaria</i>		
<i>labrolineata</i> (GASKOIN, 1849)	- :	10
<i>helvola</i> (LINNAEUS, 1758)	- :	1
<i>caputserpentis</i> (LINNAEUS, 1758)	3 :	11
<i>poraria</i> (LINNAEUS, 1758)	0 :	0
<i>erosa</i> (LINNAEUS, 1758)	4 :	9
<i>Staphylaea</i>		
<i>staphylaea</i> (LINNAEUS, 1758)	3 :	0
<i>limacina</i> (LAMARCK, 1810)	1 :	-
<i>Nuclearia</i>		
<i>nucleus</i> (LINNAEUS, 1758)	- :	1
<i>Erronea</i>		
<i>xanthodon</i> (SOWERBY, 1832)	- :	0
<i>errones</i> (LINNAEUS, 1758)	13 :	2
<i>caurica</i> (LINNAEUS, 1758)	10 :	2
<i>listeri</i> (GRAY, 1824)	16 :	1
<i>Notadusta</i>		
<i>punctata</i> (LINNAEUS, 1771)	- :	0
<i>Palmadusta</i>		
<i>asellus</i> (LINNAEUS, 1758)	0 :	1
<i>clandestina</i> (LINNAEUS, 1767)	6 :	-
<i>humphreysii</i> (GRAY, 1825)	- :	0
<i>Purpuradusta</i>		
<i>gracilis</i> (GASKOIN, 1849)	0 :	1
<i>minoridens</i> (MELVILL, 1901)	0 :	0
<i>Blasicrura</i>		
<i>pallidula</i> (GASKOIN, 1849)	1 :	12
<i>tercs</i> (GMELIN, 1791)	- :	2
<i>Bistolida</i>		
<i>hirundo</i> (LINNAEUS, 1758)	- :	1
<i>stolidia</i> (LINNAEUS, 1758)	0 :	-
<i>Ovatipsa</i>		
<i>chinensis</i> (GMELIN, 1791)	- :	0
<i>Cribrarula</i>		
<i>cribraria</i> (LINNAEUS, 1758)	1 :	0
<i>catholicorum</i> SCHILDER & SCHILDER, 1938	0 :	-

lation depends on its environment, but the average length of the sum of all populations living in larger areas evidently points to geographical characters.

MARIA SCHILDER (1967) has computed and tabulated the average length of the cowrie species and its "usual variation," *i. e.* the limits of  $\frac{2}{3}$  of specimens approaching the median. These standard figures concerning shells coming from the whole range of distribution of each species have been repeated with regard to East Australian species in column 3 of Table 7.

Table 7 contains the following 5 columns:

- 1 = number of East Australian populations containing more than 10 specimens of the species, plus 1 if the sum of single specimens coming from other localities exceeds 10;
- 2 = name of the species (see column 3 of Table 1);
- 3 = lower limit, median, and upper limit of "usual variation" in length (in mm) of the species in its whole range (M. SCHILDER, 1967).
- 4 = the same for East Australian shells, expressed by the mean of the populations the number of which is indicated in column 1;
- 5 = tendency and mathematical significance of differences in median length of the species generally (column 3) and that of East Australian shells (column 4): small letters indicate that the East Australian shells are smaller, CAPITALS indicate that they are larger than the shells coming from everywhere; the probability of the difference has been classified in four degrees:
  - a, A = both medians are within the range of usual variation of the other column (*e. g.* *Mauritia eglantina*): the difference is probably caused by chance;
  - b, B = one median only is within this range, the other is outside the other range (*e. g.* *Luria isabella*): the difference may be real;
  - c, C = both medians are outside the range of the other column, but the ranges themselves cross each other (*e. g.* *Monetaria annulus*): the difference is significant;
  - d, D = the ranges of variation indicated in column 3 and 4 exclude each other (*e. g.* *Purpuradusta minoridens*): the difference is very significant.

Table 7

1	2	3	4	5
<i>Mauritia</i>				
7	<i>eglantina</i>	44.51.58	45.49.54	a
4	<i>arabica</i>	37.44.56	55.59.64	C
<i>Talparia</i>				
1	<i>talpa</i>	52.62.72	52.61.71	a

1	2	3	4	5
<i>Cypraea</i>				
1	<i>tigris</i>	67.81.103	73.89.95	A
<i>Lyncina</i>				
1	<i>argus</i>	59.70.83	69.77.84	A
5	<i>lynx</i>	30.35.41	37.41.45	B
6	<i>vitellus</i>	36.44.54	41.48.52	A
4	<i>carneola</i>	24.28.34	32.38.45	C
<i>Luria</i>				
4	<i>isabella</i>	20.25.29	24.30.34	B
<i>Pustularia</i>				
1	<i>globulus</i>	12.16.19	17.19.20	B
1	<i>margarita</i>	11.12.15	13.17.19	C
2	<i>cicercula</i>	14.16.19	16.17.19	A
2	<i>bistrinotata</i>	13.15.18	15.17.18	A
<i>Monetaria</i>				
10	<i>annulus</i>	16.19.22	21.24.26	C
6	<i>moneta</i>	16.20.25	23.25.27	C
<i>Erosaria</i>				
7	<i>labrolineata</i>	12.14.18	18.20.23	C
1	<i>tomlini</i>	12.18.24	19.26.29	C
1	<i>helvola</i>	17.20.23	19.23.27	A
10	<i>caputserpentis</i>	25.29.32	29.31.34	A
13	<i>erosa</i>	25.30.35	29.33.38	A
1	<i>eburnea</i>	33.38.44	35.37.40	a
<i>Staphylaea</i>				
5	<i>staphylaea</i>	11.15.19	17.19.22	B
2	<i>limacina</i>	19.24.28	23.26.30	A
<i>Nuclearia</i>				
2	<i>nucleus</i>	16.19.23	22.23.25	B
<i>Erronea</i>				
1	<i>walkeri</i>	20.23.28	22.26.28	A
14	<i>xanthodon</i>	23.26.29	23.26.29	.
3	<i>subviridis</i>	26.30.35	26.30.34	.
17	<i>errones</i>	19.23.28	22.26.29	A
3	<i>cylindrica</i>	24.28.33	24.27.31	a
8	<i>caurica</i>	29.35.41	35.39.42	A
4	<i>listeri</i>	12.15.18	17.19.21	C
<i>Notadusta</i>				
1	<i>punctata</i>	9.11.14	10.13.15	A
<i>Palmadusta</i>				
2	<i>asellus</i>	13.15.17	15.17.21	A
7	<i>clandestina</i>	11.14.17	14.16.17	A
2	<i>lutea</i>	12.15.19	15.16.17	A
<i>Purpuradusta</i>				
12	<i>gracilis</i>	14.16.19	15.17.19	A
1	<i>hammondae</i>	12.14.15	13.14.16	=
2	<i>minoridens</i>	7. 8. 9	10.11.12	D
<i>Blasicrura</i>				
2	<i>quadrinaculata</i>	17.20.23	19.20.22	=
4	<i>pallidula</i>	15.16.19	17.20.22	B
2	<i>teres</i>	21.24.29	26.30.34	C
<i>Bistolida</i>				
1	<i>kieneri</i>	11.13.18	12.14.16	A
2	<i>hirundo</i>	12.15.17	15.17.19	A
4	<i>stolidia</i>	21.24.29	21.22.26	a
<i>Cribrarula</i>				
1	<i>cribraria</i>	17.21.26	20.22.25	A

The frequency of differences entered in column 5 of Table 7 is in 43 species as follows (*Erronea xanthodon* and *E. subviridis* must be omitted, as the former is totally restricted to East Australia and most typical *E. subviridis* (s. str.) examined also came from this region only):

d	c	b	a	=	A	B	C	D	
-	-	-	5	2	20	6	9	1	species.

In East Australia no cowrie species is really smaller than in other regions, and 5 species only are possibly smaller; most species are distinctly larger, 16 species even more or less significantly larger than usual. This fact may be caused by the general tendency in many cowrie species to grow larger in peripheral regions than in the central areas (SCHILDER, 1961, GRIFFITHS, 1964), especially in colder zones (SCHILDER, 1964).

### The Size in Different Populations

Table 8 shows the following columns:

- 1 = the name of the species represented by a sufficient number of shells in at least 2 localities;
- 2 = the median length and the usual variation of East Australian specimens as indicated in column 4 of Table 7;
- Q to Z = the 10 sets enumerated in Table 3; each of these 10 columns shows the median length of the shells collected in the set and the letter indicating the significance of differences as explained above (Table 7, column 5), but here comparing the local sizes with those observed in East Australia generally (column 2).

The mean of negative and positive differences between the local sizes of various species and those in the whole region of East Australia shows that several populations (S, W, Y, Z) are typical; in R, V, X, and especially in Q (Holborne Island) the shells are rather small, while they are rather large in T (Middle Island) and very large in U (Humpy Island). However, in each locality the cowrie species differ much in relative size: so, for instance, in U (Humpy Island) *Mauritia eglantina* and *M. arabica* are very large, but *Erronea subviridis* is rather small, and in X (Mooloolaba) *Erosaria caputserpensis* is small, but *Erronea erronea* is very large.

The divisible sets T, U, and V treated above in Tables 4 to 6 show interesting differences between the parts. Table 9 enumerates species represented in sufficient numbers in both parts indicated in the 3 headlines, and shows the median and the usual variation in each part, followed by the letter indicating the significance of the difference of the first column if compared with the second.

Table 9

U [Humpy Island]	1963	1964	
<i>Erosaria</i>			
<i>erosa</i> (LINNAEUS, 1758)	34.36.38	33.34.40	A
<i>Erronea</i>			
<i>xanthodon</i> (SOWERBY, 1832)	25.28.30	25.28.30	=
<i>subviridis</i> (REEVE, 1835)	27.29.31	25.28.29	A
<i>errones</i> (LINNAEUS, 1758)	26.28.31	25.28.31	=
<i>caurica</i> (LINNAEUS, 1758)	40.43.48	37.41.47	A
<i>Purpuradusta</i>			
<i>gracilis</i> (GASKOIN, 1849)	17.18.20	18.19.20	a
T [Middle Island]	1964	1965	
<i>Erronea</i>			
<i>xanthodon</i> (SOWERBY, 1832)	24.26.29	23.25.29	A
<i>errones</i> (LINNAEUS, 1758)	26.28.30	23.26.29	A
<i>Purpuradusta</i>			
<i>gracilis</i> (GASKOIN, 1849)	17.18.19	15.17.18	A
V [One Tree Island]	living	beach	
<i>Mauritia</i>			
<i>eglantina</i> (DUCLOS, 1833)	46.53.58	41.46.52	B
<i>arabica</i> (LINNAEUS, 1758)	52.56.62	44.48.54	C
<i>Lyncina</i>			
<i>vitellus</i> (LINNAEUS, 1758)	37.39.44	36.42.50	a
<i>carneola</i> (LINNAEUS, 1758)	33.35.40	29.34.39	A
<i>Erosaria</i>			
<i>caputserpensis</i> (LINNAEUS, 1758)	32.34.36	28.31.34	B
<i>erosa</i> (LINNAEUS, 1758)	34.36.38	26.31.34	C
<i>Erronea</i>			
<i>errones</i> (LINNAEUS, 1758)	22.25.27	21.24.27	A
<i>caurica</i> (LINNAEUS, 1758)	36.38.41	37.40.43	a

The letters indicating the differences show that in Humpy Island (U) the length of species is practically identical in the two subsequent years, while in Middle Island (T) the fresh specimens of 1964 are altogether slightly larger than in 1965, and in One Tree Island (V) the live collected specimens of many species are distinctly larger than the beach shells, but only 2 species are possibly smaller (see COUCOM & SCHILDER, 1967)! One will observe that this sequence agrees with that of differences in frequency of species in these sets (see Tables 4 to 6).

### Results

Our extensive studies in East Australian cowries show that both the relative frequency of species and the average size of shells in this region can be approximately estimated by the mean of 10 sets of at least 250 shells, the sets being collected in different parts of the region with partly different environments. Several widely distributed species evidently differ in frequency in East Australia from that

Table 8

1	2	Q	R	S	T	U	V	W	X	Y	Z
<i>Mauritia</i>											
<i>eglantina</i> (DUCLOS, 1833)	45.49.54	48 a	47 a	49 =	.	67 D	47 a	.	.	.	.
<i>arabica</i> (LINNAEUS, 1758)	55.59.64	.	.	.	63 B	67 D	50 c	.	.	.	.
<i>Lyncina</i>											
<i>lynx</i> (LINNAEUS, 1758)	37.41.45	.	42 A	41 =	.	.	36 c	.	.	.	.
<i>vitellus</i> (LINNAEUS, 1758)	41.48.52	.	50 A	48 =	.	.	40 c	.	.	.	49 A
<i>carneola</i> (LINNAEUS, 1758)	32.38.45	34 a	.	.	.	.	35 a	.	.	43 A	.
<i>Luria</i>											
<i>isabella</i> (LINNAEUS, 1758)	24.30.34	29 a	28 a	.	.	.	30 =	.	.	.	.
<i>Monetaria</i>											
<i>annulus</i> (LINNAEUS, 1758)	21.24.26	.	20 c	24 =	.	.	23 a	.	.	24 =	25 A
<i>moneta</i> (LINNAEUS, 1758)	23.25.27	.	.	25 =	.	.	26 A	.	.	26 A	23 a
<i>Erosaria</i>											
<i>labrolineata</i> (GASKOIN, 1849)	18.20.23	17 c	.	.	.	.	17 c	20 =	20 =	20 =	21 A
<i>caputserpentis</i> (LINNAEUS, 1758)	29.31.34	.	.	31 =	.	.	32 A	30 a	28 b	31 =	32 A
<i>erosa</i> (LINNAEUS, 1758)	29.33.38	28 b	33 =	33 =	.	36 A	33 =	33 =	32 a	34 A	33 =
<i>Staphylaea</i>											
<i>staphylaea</i> (LINNAEUS, 1758)	17.19.22	.	.	.	.	.	22 A	19 =	18 a	19 =	.
<i>Erronea</i>											
<i>xanthodon</i> (SOWERBY, 1832)	23.26.29	.	.	.	26 =	28 A	.	25 a	25 a	28 A	.
<i>subviridis</i> (REEVE, 1835)	26.30.34	.	.	.	.	28 a	.	.	.	31 A	.
<i>errones</i> (LINNAEUS, 1758)	22.26.29	18 d	21 c	23 b	28 A	28 A	25 a	25 a	31 C	.	.
<i>cylindrica</i> (BORN, 1778)	24.27.31	28 A	24 a	.	.	.	.	.	.	.	.
<i>caurica</i> (LINNAEUS, 1758)	35.39.42	35 c	38 a	36 b	.	42 B	39 =	.	.	39 =	.
<i>listeri</i> (GRAY, 1824)	17.19.21	.	.	.	.	.	18 a	20 A	.	.	.
<i>Palmadusta</i>											
<i>clandestina</i> (LINNAEUS, 1767)	14.16.17	.	.	16 =	.	.	16 =	16 =	16 =	16 =	14 b
<i>Purpuradusta</i>											
<i>gracilis</i> (GASKOIN, 1849)	15.17.19	16 a	15 b	18 A	17 =	19 B	.	16 a	16 a	18 A	.
<i>Blasicrura</i>											
<i>pallidula</i> (GASKOIN, 1849)	17.20.22	18 a	18 a	.	.	.	22 A	.	.	.	.
<i>Bistolida</i>											
<i>stolida</i> (LINNAEUS, 1758)	21.22.26	.	.	.	.	.	.	22 =	22 =	.	.

in other regions, and the size of most species is larger in East Australia than in the tropics.

These 10 sets, however, differ each from the other both with regard to relative frequency of species and to average size of specimens; these differences seem to be partly caused by mere chance, but in both ways certain regional tendencies cannot be denied. There are similarities in adjacent localities and great differences between collections made in the same locality at different times or in different conditions.

These results seem to be rather poor and need confirmation by similar collections in other regions. Nevertheless, we think our provisional investigations worth publishing.

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# The Muricidae of Fiji

(Mollusca : Gastropoda)

Part I Subfamilies Muricinae and Tritonaliinae

Plus an Addendum with Text figure 11

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

(Plates 14, 15; 10 Text figures; 1 Map)

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(\* denotes synonym or homonym)

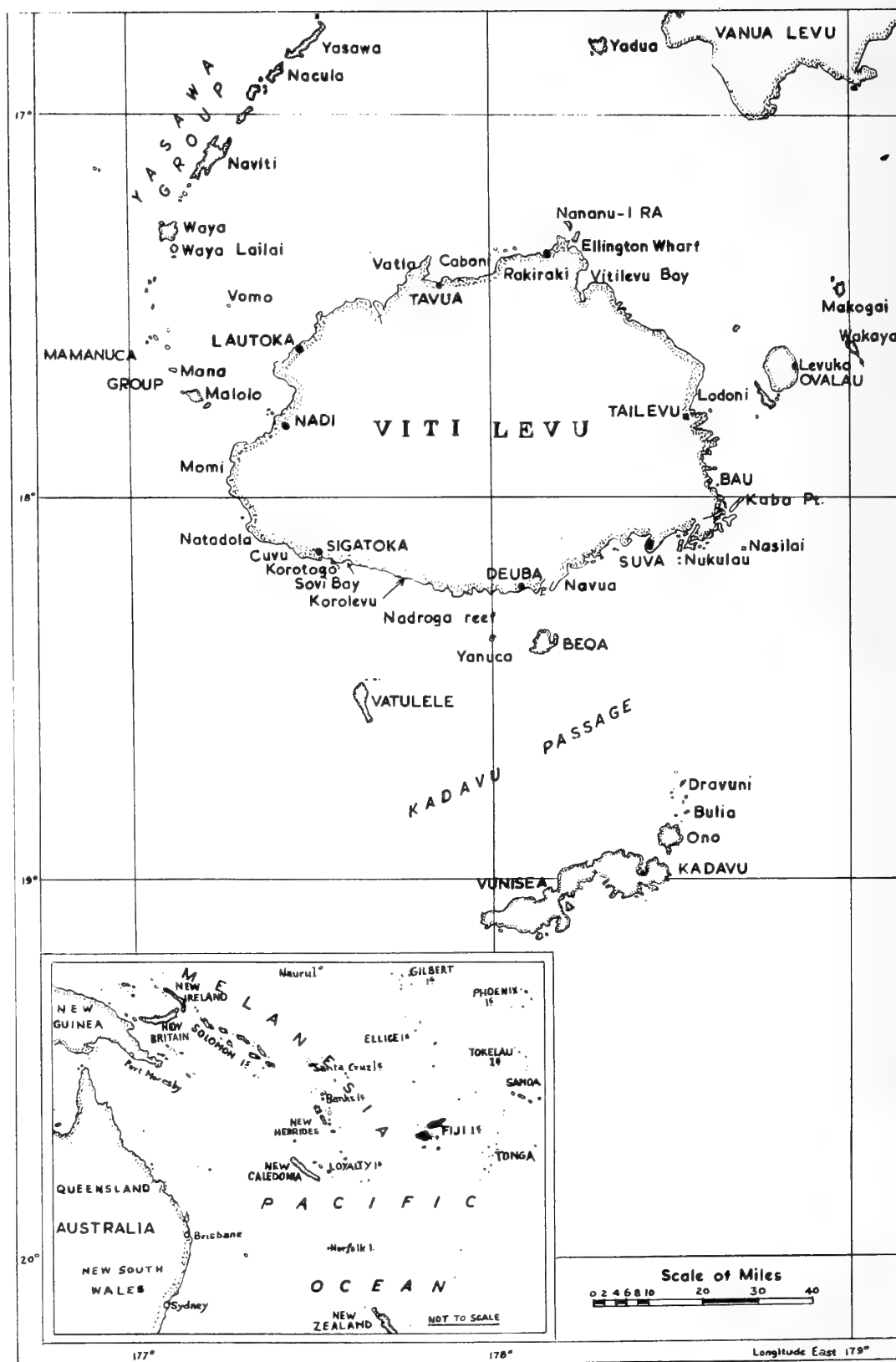
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THIS IS THE SEVENTH PART in the series of faunal monographs dealing with the marine mollusca of the Fiji Islands.

In accordance with past procedures only species collected by resident collectors and the author are listed as verified records. Fiji specimens preserved in Museums and private collections outside the Fiji Islands shall be

taken into consideration at a later stage, provided that collecting data are reliable.

Species recorded from Fiji have a wide-ranging distribution in the Indo-Pacific, living in an area extending from the Red Sea to the Tuamotu Archipelago. Members of the two subfamilies discussed below are confined within tropical to temperate waters between Latitudes 40° N to



40° S. The area between Southern Japan-Philippines-Northeast Australia (Longitude 120° E to 150° E) is the richest in muricine species. About 35 muricine species have been recorded from Japan and Australia, and there is an appreciable fall-off in the number of species living to the West and East of this central Indo-Pacific region: South Africa 7 species, East Africa 9 and Aden about 10 species. In the easterly direction the number of species declines to 16 in Fiji, 10 in the Society Islands-Tuamotu Archipelago region and less than half a dozen species in the Hawaiian Islands. Other groups of Mollusca, particularly tropical gastropod forms, attain their optimum distributional densities within this geographical area.

For notes on the geography of the Fiji Islands and other pertinent data see CERNOHORSKY (1964).

### THE ANIMAL

The animal's foot is moderate in size but powerful, the mantle is thin and generally of the same colour as the foot. The siphon is simple, tentacles are moderately short and stubby, and simple eyes are positioned on the outside of the thickened base of the tentacles. Sexes are separate, and the penis which is situated behind the right tentacle is thickened at the base but slender, whip-like and curved at the distal end; the size of the male verge will vary from 14% to 20% of shell-length.

The proboscis is long and slender and the radular ribbon of specimens examined varied from 4 mm to 24 mm in length. The radula, which is of the rhachiglossate type, contains about 100 to 300 rows of teeth, each row consisting of a multicuspid rhachidian and simple unicuspid and curved laterals. The first dozen rows of teeth are greatly worn, and broken cusps may often persist for another dozen rows. In the subfamily Muricinae the rhachidian has either 3 larger main cusps and 2 intermediate denticles or 3 large cusps only. In the Tritonaliinae the rhachidian is equipped with 3 to 5 main cusps and with from 3 to 6 small, vertically incised secondary denticles.

The operculum is generally brown to yellowish-brown in colour, corneous, and attached to the foot by the scabrous part of the interior opercular lining, while a semicircle portion is smooth and glazed. The nucleus is either basal, latero-basal or off-central in Muricinae; in the Tritonaliinae the nucleus is mostly dextro-lateral or occasionally latero-basal. As pointed out by VOKES (1964) no great reliance can be placed on the opercular nucleus in the determination of a subfamilial position, since members of other muricid subfamilies possess both types of opercula.

Muricidae are active predators and borers; they do not confine their hole-drilling to any particular group of mol-

lusks but prey on almost all species of gastropods and pelecypods. The holes bored by muricids into the shells of other molluscs are perfectly circular on the outer rim, with the widest diameter at this part, and then slightly converge towards the interior of the shell. The break-through point is less perfect and somewhat irregular. Because of their geometrical outline, these muricid holes have on occasion been mistaken for man-made holes and classed as artifacts by archaeological excavators.

An accessory boring organ located near the anterior part of the foot has been reported by CARRIKER (1961) in some species of Muricidae. Although some writers have attributed a dissolving or softening effect to the secretion of the accessory salivary glands, the actual boring process appears to be mainly mechanical. The secretion of a proteolytic enzyme during boring in Muricidae (MAN-SOUR-BEK, 1934) undoubtedly would assist during the boring process as a lubricant and absorber of small fragments of calcium carbonate. GRAHAM (1941) reports the secretion of the accessory salivary gland of the muricid *Nucella lapillus* (LINNAEUS, 1758) to have a pH of 6, and to have no dissolving effect on calcium carbonate. A similar secretion was observed by the author in the cyp-raeid *Mauritiana eglantina* (DUCLOS, 1833), which is an algae- and deposit-feeder, and not a borer. The muricid species *Hexaplex pomum* (GMELIN, 1791) does not have accessory salivary glands (CARRIKER, 1961), and the boring process is therefore purely mechanical in this species. In view of the group's anatomical features and feeding habits, the Muricacea are regarded to be in a more primitive stage of development than the two other stenoglossan superfamilies Buccinacea and Volutacea (FRETTER & GRAHAM, 1962).

### SHELL AND HABITAT

Species of the genus *Murex* s. str. are especially vulnerable to predators due to the moderate thickness of the shell and wide open aperture; the prominent sharp spines may have developed in this group as a compensatory defence feature. Species of the subgenus *Haustellum* SCHUMACHER, 1817, have retained the wide-open apertures, but the shell has become thicker and heavier and the spines have become degraded or obsolete. In *Chicoreus* MONTFORT, 1810 shells are rather solid and spines have changed into shorter fronds. In the large species of *Chicoreus* and *Phyllonotus* SWAINSON, 1833, the aperture is still wide open, but the shells are so large and solid that it would prove difficult for predators to dislodge the shell or gain access to the apertural opening when the animal is reposing on the substratum with the aperture downward. The smaller

species of *Chicoreus*, still retaining their solid shell, have a reduced apertural size which compensates for their smaller size and lighter weight. In the *Pterynotus-Nauctia* group species have lost the spines or fronds, but have become smaller and more slender in form, a distinct advantage in coral-reef environment, and their apertural opening is reduced. Living species of Muricinae show therefore a certain correlation of compensating characters of shell-weight and thickness, size, degree of prominence of spines and apertural size.

In Fiji specimens examined, the colour and size of the shell, apertural colouring, size and number of spines or fronds, sculpture, columellar denticulation were found to be subject to ecologic and individual variation; a similar degree of variation has been reported by WU (1965). The general form of the shell, number of varices, labial denticulation and length of siphonal canal were less prone to vary, and surprisingly consistent in many species.

Fijian Muricidae are always associated with coral reefs; the majority of species flourish in muddy-sand environment, while species like *Chicoreus ramosus* (LINNAEUS, 1758) favour a clean sand environment, and *Pterynotus triqueter* (BORN, 1778) occurs in both clean and muddy sand localities. Most species inhabit the intertidal zone while only a few species live in deeper water. Some intertidal species, e. g. *Chicoreus carneolus* (RÖDING, 1798) can exist under the most adverse conditions and even flourish. During heavy floods on the Island of Viti Levu, whole molluscan populations of coastal reefs were completely destroyed due to the inundation of fresh water in sheltered bays. *Chicoreus carneolus*, however, survived without any ill effects or reduction in numbers.

### TAXONOMY

A recent account of the taxonomy of muricids and supra-specific arrangement of the subfamilies Muricinae and Tritonaliinae has been published by VOKES (1964), and no duplication is intended here. In Muricidae as in other groups of Mollusca, supraspecific taxonomy has received more attention than taxonomy on the specific level. The taxonomic works of RÖDING (1798) and LINK (1807), both binomial catalogues containing numerous generic and specific names, have been brought to the attention of malacologists early in this century. Yet in the last 50 years little attention has been directed to the elucidation of new taxa contained in these works. Efforts have been made, commendable ones, to be sure, to elucidate the true authorship of works published anonymously, while the

actual contents have largely remained ignored. Consequently many Lamarckian names adopted by subsequent writers continue to remain in use, names which should have been replaced by valid prior ones.

Valid but forgotten names which have been rushed into print before 1960 are taxonomically acceptable, while such names introduced into literature after 1960 qualify as *nomina oblita* (art. 23b, Code of ICZN, 1964). Many zoologists feel that insufficient time has been granted to the elucidation of names introduced in works which have come to the attention of workers in recent years. In view of the current dispute about art. 23b of the Code of ICZN (1964) *nomina oblita* which have been simply rejected by the International Commission on Zoological Nomenclature, must be suppressed under the plenary powers (in litt., Assist. ICZN, 10 October 1966). Matters are further complicated in so far that a name which has been used in primary literature on the subject in the last 50 years is taxonomically valid, whereas a name appearing in secondary literature is not. No definition on what constitutes primary or secondary zoological literature has been offered by the International Commission on Zoological Nomenclature, and the interpretation therefore rests with every individual worker.

The three RÖDING names re-introduced here into muricid literature may after all not qualify as *nomina oblita*, as they could have been mentioned in the literature on the subject in the last 50 years. In view of the taxonomic problems involved in this particular case, it was thought advisable to accept the prior names; in one instance the existing name is a possible homonym, while in another instance a later but equally new name would have to be substituted.

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## NEOGASTROPODA

## MURICACEA

## MURICIDAE

## Muricinae

*Murex* LINNAEUS, 1758

*Murex* LINNAEUS, 1758, Syst. Nat., ed. 10, p. 746 – Type species by SD (GRAY, 1847) *Murex tribulus* LINNAEUS, 1758

**Characters:** Shell moderately light in weight, spire elevated, whorls convex; spines slender and pointed, somewhat curved, closed, alternating between short and long. Sculpture consists of 3 varices per whorl, plain or gemmate axial cords, axial riblets in interstices and axial ribs on earlier whorls. Aperture wide and open, roundly ovate, columella smooth, edge of labial lip bluntly denticulate; siphonal canal generally slender and long, spinose, and with a narrow central slit on the ventral side. Operculum with a basal or sinistro-lateral nucleus. Rhachidians of radula with 3 large main cusps and 2 smaller intermediate denticles, laterals simple and unicuspid.

**Discussion:** VOKES (1964) in her revision of the group cited *Murex tribulus* LINNAEUS as the type species of *Murex* s. str. by subsequent designation of MONTFORT (1810) as *Murex pecten* MONTFORT. MONTFORT (*op. cit.*, p. 619) did not cite *M. tribulus* LINNAEUS but rather *M. pecten* as the type of *Murex*, and his illustration on the opposite page as well as his figure references represent *Aranea triremis* PERRY, 1811 (= *Murex pecten* LIGHTFOOT, 1786), a similar but distinct species. MONTFORT's type designation is invalid, since his *M. pecten* is not synonymous with *M. tribulus* LINNAEUS, nor was *M. pecten* one of the originally included nominal species (art. 69(a) (i), Code of ICZN, 1964).

*Murex pecten* MONTFORT, 1810, although an earlier name for the species *M. triremis* (PERRY, 1811), is a primary homonym of *M. tribulus* var. *pecten* LIGHTFOOT, 1786 (p. 188, no. 4001 – based on RUMPHIUS [1705], t. 26, fig. 3). The cited figure is the "Dubbeldc Spinnekop" of RUMPHIUS, and is the same species as *M. triremis* (PERRY) and *M. tenuispina* LAMARCK, 1822. *Murex pecten* LIGHTFOOT, 1786, should therefore replace PERRY's later *M. triremis*.

(*Murex* s. str.)

*Murex trapa* RÖDING, 1798

(Plate 14, Figure 1)

1798. *Murex trapa* RÖDING, Mus. Bolten., p. 145, no. 1817 (ref. MARTINI, 1777, 3, t. 113, figs. 1055, 1056)

1822. *Murex rarispina* LAMARCK, Hist. nat. anim. sans vert., 7: ref. MARTINI, *op. cit.*, fig. 1056)

1845. *Murex martinianus* REEVE, Conch. Icon., 3, pl. 18, sp. 72 (ref. MARTINI, *op. cit.*, fig. 1056) [non PFEIFFER, 1840]

1965. *Murex trapa* RÖDING, SHI-KUEI WU, Bull. Inst. Zool. Acad. Sinica 4: 98, fig. 13 (radula)

**Shell:** Shell light in weight, base colour creamy-white, spiral cords on body whorl white or creamy-white, interstices rusty-brown. Teleoconch with 7 whorls, protoconch with  $1\frac{1}{2}$  - 2 smooth brown nuclear whorls. Sculptured with smooth or gemmate spiral cords, 3 varices at every whorl and close-set axial riblets in interstices. Spines moderately long, sharp, closed and somewhat recurved; primary spines number from 3 - 6 on the labial varix and from 4 - 5 on the siphonal canal. Aperture wide and oval, labial lip with 11 - 16 denticles, columella white and smooth, deep interior of aperture brown. Siphonal canal long, slender and spinose, slit on ventral side open. Operculum with a basal nucleus.

**Size:** 60 mm to 110 mm.

**Type locality:** None. The specimens illustrated by MARTINI (1777) were reported from Amboina and Tranquebar. "Amboina, Indonesia" is designated as type locality.

**Habitat:** In muddy sand, in shallow water. Not uncommon in Southeast Viti Levu (Lodoni jetty), but rare elsewhere.

**Distribution:** North and South Viti Levu. – From Indonesia to Japan, East Australia and the Fiji Islands.

**Discussion:** The species is similar to *Murex tribulus* LINNAEUS, but differs in characters of creamy-white spines and spiral cords, brown interstices, somewhat fewer and shorter spines, coarser sculpture on the penultimate and earlier whorls, and an irregular siphonal canal.

*Murex tribulus* LINNAEUS, 1758

(Plate 14, Figure 2)

1758. *Murex tribulus* LINNAEUS (pars), Syst. Nat., ed. 10, p. 746, no. 444 (first ref. COLUMNA, 1616, t. 60, fig. 6)

1817. *Murex scolopax* DILLWYN, Descr. cat. rec. shells 2: 681 (ref. MARTINI, 1777, 3: t. 113, fig. 1052 and CHEMNITZ, 1795, 11, t. 189, figs. 1819, 1820)

1822. *Murex ternispina* LAMARCK, Hist. nat. anim. sans vert. 7: 158 (no figures cited)

1822. *Murex crassispina* LAMARCK, Hist. nat. anim. sans vert. 7: 157 (MARTINI, *op. cit.*, t. 113, figs. 1052-1054 and CHEMNITZ, *op. cit.*, t. 189, figs. 1819, 1820)

1845: *Murex nigrispinosus* REEVE, Conch. Icon., 3, pl. 20, sp. 79

1913: *Murex (Tribulus) ternispina* LAMARCK, SCHEPMAN, Sib. Exped. 49 d: 341

1913. ? *Murex (Tribulus) ternispina* var. *rufolirata* SCHEPMAN, Siboga Exped. 49 d: 342

1957. *Murex crassispina* [sic] LAMARCK, DODGE, Bull. Amer. Mus. Nat. Hist. 113 (2): 82-83

**Shell:** Uniformly creamy-white to brown in colour. Teleoconch with 7 - 8 whorls, protoconch with 2 smooth, glassy-brown nuclear whorls. Sculptured with clathrate spiral

cords, 3 varices per whorl, and close-set and gemmate axial ridges in interstices. Spines long, sharp, closed and recurved; primary spines number from 6 - 8 on the labial varix and from 4 - 6 on the siphonal canal. Aperture wide and oval, labial lip with 10 - 15 denticles, some of which are paired; columella white and smooth, anal notch obsolete, deep interior of aperture brown. Siphonal canal long, slender, straight and spinose. Operculum with a basal nucleus.

**Size:** 70 mm to 120 mm.

**Type locality:** O. Asiae. (Java, Indonesia).

**Habitat:** in clean and muddy sand and coral rubble substratum, from 1 - 7 fathoms. Moderately common.

**Distribution:** Throughout the Fiji Islands. — From the Red Sea and the Gulf of Oman to Japan, East Australia and the Fiji Islands.

**Discussion:** From the 7 figures cited by LINNAEUS (1758), 4 figures depict *Murex tribulus* auctt., and 3 figures represent *M. pecten* LIGHTFOOT. LAMARCK (1822) cited MARTINI's figures 1052 - 1054 for his *M. crassispina*. These figures represent *M. tribulus* and were cited for this species by both RÖDING (1798) and LINK (1807); figure 1052 was cited by DILLWYN (1817) for *M. scolopax*.

*Murex nigrispinosus* REEVE, a variant of *M. tribulus* with black-tipped spines, appears to be restricted to the Western Pacific and does not occur in Fiji. Neither does *M. pecten* LIGHTFOOT, which differs from *M. tribulus* in having more numerous and geometrically arranged spines; the spines on the siphonal canal are wider apart in *M. tribulus*, having a spacing of ca. 4.5 mm to 6.5 mm, whereas in *M. pecten* the width between the spines is only 3 mm to 4 mm.

The length of spines in *Murex tribulus* is variable: the longest spine, which is generally situated on the dorsal varix on the body whorl, measured from 12 mm to 50 mm in specimens examined.

(*Haustellum*) SCHUMACHER, 1817

*Haustellum* SCHUMACHER, 1817, Essai Nouv. Syst., p. 213 — Type species by *Murex haustellum* LINNAEUS, 1758

**Characters:** Shell solid and globular, spire elevated, whorls convex and with a presutural keel, spines absent or few and thornlike. Whorls number 8, varices 3, early whorls sculptured with axial riblets and spiral striae, later whorls striate and nodulose. Aperture wide and oval, elevated, labial lip obsoletely denticulate, labrum plicate, columella smooth or plicate, anal notch prominent and formed like an inverted  $\Omega$ . Siphonal canal slender and long, slit on ventral surface open. Operculum with an off-central nucleus.

*Murex (Haustellum) haustellum* LINNAEUS, 1758

(Plate 14, Figure 3)

1758. *Murex haustellum* LINNAEUS, Syst. Nat., ed. 10, p. 746, no. 443 (first ref. BUONANNI, 1684, 3, t. 268)

1798. ? *Murex scolopaceus* RÖDING, Mus. Bolten., p. 144, no. 1813 (ref. FAVANNE, 1780, t. 38, fig. B2)

1811. *Aranea denudata* PERRY, Conchology, pl. 45, fig. 1 (non *Triplex denudata* PERRY, 1811, pl. 7 = *Chicoreus* sp.)

1817. *Haustellum laeve* SCHUMACHER, Essai Nouv. Syst., p. 213

1840. *Murex erythrostoma* SWAINSON, Treat. Malac., p. 296 (non *M. erythrostomus* SWAINSON, 1831)

1891. *Murex haustellum* var. *longicaudus* BAKER, Proc. Acad. Nat. Sci. Philadelphia, p. 56 (non WOOD, 1828)

1964. *Murex (Haustellum) kurodai* SHIKAMA, Venus: Japan. Journ. Malac., 23 (1): 35, pl. 3, figs. 1, 2

**Shell:** Shell solid and globular, creamy-white to fawn in colour, variously maculated with brown. Teleoconch of 8 convex whorls, protoconch missing in specimens examined. Early whorls sculptured with axial ribs and spiral striae, later whorls nodulose, nodules most prominent on presutural keel; varices prominent, numbering 3 per whorl, spines absent or few and thorn-like. Aperture wide and oval, elevated, labial lip with small denticles, labrum with short plicae. Columella creamy-white to orange, smooth or plicate; interior of aperture white, anal notch distinct and moderately deep. Siphonal canal long, thickened at base but tapering to distal end, slit on ventral surface narrow.

**Size:** 80 mm to 125 mm.

**Type locality:** O. Asiae.

**Habitat:** On sand and coral-rubble substratum, in 2 to 3 fathoms. Rare.

**Distribution:** North and South Viti Levu and Yasawa group. — From the Red Sea to Japan, East Australia and the Fiji Islands.

*Chicoreus* MONTFORT, 1810

*Chicoreus* MONTFORT, 1810, Conchyl. Syst., 2: 611 — Type species by *OD Murex ramosus* LINNAEUS, 1758

**Characters:** Shell heavy and solid, spire elevated, whorls convex; spines frondose and prominent, closed or open, sometimes recurved. Sculptured with spiral striae, axial riblets and nodules. 3 varices per whorl and nodes between varices. Aperture wide and oval in the type-species, but less large in smaller species. Labial lip dentate, columella smooth or occasionally denticulate, calloused, anal notch prominent. Siphonal canal broad, only moderately long, slit on ventral surface open.

Operculum with a sub-basal or basal nucleus. Radula similar to that of *Murex* s. str. but the base of the rhachidians is generally less broad and somewhat higher than in

*Murex*; the central main cusp is longer than the flanking main cusps, the 2 intermediate denticles are either moderately large or small.

**Discussion:** For remarks on the type-species see under *Chicoreus ramosus* (LINNAEUS).

*Chicoreus aculeatus* (LAMARCK, 1822)  
(Plate 14, Figure 5; Text figure 1)

1822. *Murex aculeatus* LAMARCK, Hist. Nat. anim. sans vert., 7: 163 (no figures cited; non *Aranea aculeata* PERRY, 1811 = *Murex* s. str.)

**Shell:** Shell light in weight, reddish-brown in colour, varices and siphonal canal occasionally tinged with lavender. Teleoconch of 6 to 7 whorls, protoconch with  $1\frac{1}{2}$  to 2 smooth and mammillate nuclear whorls. Sculptured with strong and weak finely beaded spiral ridges, 3 varices per whorl and nodes between varices. The frondose spines are very short or obsolete on the first three mature whorls, but moderately produced on later whorls; the spines number from 5 to 8 on the labial varix and from 2 to 4 on the siphonal canal. Aperture small and oviform, rose-violet or lavender in colour, deep interior bluish; labial lip with 10 to 15 denticles, columella smooth, anal notch distinct. Siphonal canal irregular and moderately produced, recurved, slit on ventral side open.

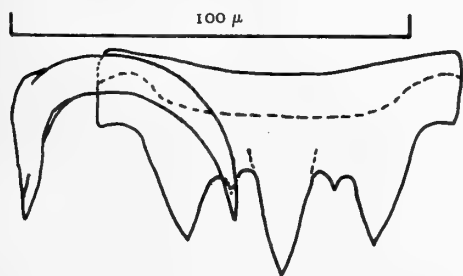


Figure 1

Half-Row of Radular Teeth of *Chicoreus aculeatus* (LAMARCK)  
Fiji Islands

**Radula:** The radula is of the *Chicoreus* type, with 3 main cusps and 2 intermediate denticles on the rhachidian; rhachidians are light brown in colour, laterals translucent white. Length of ribbon 4.6 mm, width 0.14 millimeters in a shell 25.0 mm in length; 164 rows of teeth (+ 26 nascentes) were counted in this example (Text figure 1).

**Size:** 22 mm to 38 mm.

**Type locality:** None. ("L'Océan Indien," KIENER, 1843).

**Habitat:** On sand and coral-rubble substratum in 10 to 15 fathoms. Rare.

**Distribution:** Mamanuca group, Fiji Islands. — From the Philippines to Japan and the Fiji Islands.

**Discussion:** *Murex aculeatus* LAMARCK is not a secondary homonym of *Aranea aculeata* PERRY, 1811 (pl. 46, fig. 2) which is a *Bolinus* species of the genus *Murex* s. str.

*Chicoreus brunneus* (LINK, 1807)  
(Plate 41, Figure 6; Text figure 2)

1807. *Purpura brunnea* LINK (pars), Besch. Nat.-Samml. Univ. Rost., 3te Abth., p. 121 (ref. MARTINI, 3, t. 105, figs. 990, 991 only)

1811. *Triplex rubicunda* PERRY, Conchology, pl. 6, fig. 4 (non *Purpura rubicunda* RÖDING, 1798; nec *Murex rubicunda* PERRY, 1811, pl. 54)

1822. *Murex adustus* LAMARCK, Hist. nat. anim. sans vert., 7: 161 (ref. MARTINI, *op. cit.*, figs. 990, 991)

1854. *Murex despectus* A. ADAMS, Proc. Zool. Soc. London for 1853: 71

**Shell:** Shell solid and heavy, generally blackish-brown in colour, blackish cords appearing on a lighter background; spire elevated, whorls convex. Teleoconch consisting of 6 whorls, protoconch of 2 nuclear whorls which are calcified in adult specimens; juvenile shells have a protoconch of 2 smooth, light-brown nuclear whorls. Sculptured with strong spiral cords and intermediate spiral ridges, 3 varices per whorl (4 on early whorls) and a prominent node

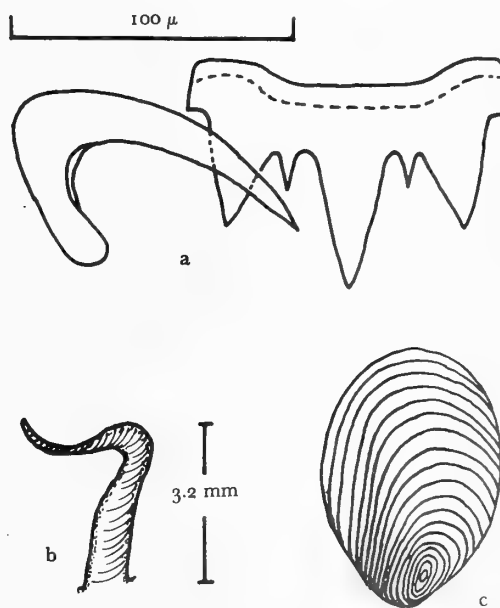


Figure 2

*Chicoreus brunneus* (LINK)  
a. Half-Row of Radular Teeth    b. Penis    c. Operculum  
Fiji Islands

between varices. The frondose spines are thick, heavily foliated and close-set, central labial fronds generally recurved. Aperture moderate in size, roundly oviform, rosyrred at edges, deep interior white; labial lip elevated, ornamented with 13 to 23 irregular denticles, columella smooth, anal notch distinct. Siphonal canal broad and short, slit on ventral side open.

**Radula:** The radula (Text figure 2) is of the *Chicoreus* type with 3 main cusps and 2 intermediate denticles on rhachidian. The radular ribbon is 7.1 mm long and 0.24 millimeters wide in a shell 42.0 mm in length; the first dozen rows of teeth are badly worn, cusps on rhachidians worn down to the base. Fully-formed rows of teeth number 187 (+ 26 nascentes). Operculum with a basal nucleus.

**Size:** 25 mm to 85 mm.

**Type locality:** None. MARTINI (1777) mentioned Banda, Amboina and Taekang Besi as localities for the species. "Banda Island, Indonesia" is designated as type locality.

**Habitat:** Under coral rocks, on clean sand or coral substratum, in shallow water. Moderately common.

**Distribution:** Throughout the Fiji Islands. — From East Africa to Japan, Australia and Samoa.

**Discussion:** LINK's *Purpura brunnea* is a composite species, based on MARTINI's figures 990, 991, 993, and 994. The first 2 figures represent *P. brunnea* LINK which is the *Murex adustus* of LAMARCK and authors. The latter 2 figures, however, depict *M. capucinus* RÖDING and LAMARCK. TOMLIN & WINCKWORTH (1936) arrived at the same conclusion in their analysis of LINK's species. The type figures are therefore here restricted to MARTINI, 1777, 3, t. 105, figs. 990 and 991.

COTTON (1956) included the Queensland species *Murex australiensis* A. ADAMS, 1853 and the New Caledonian *M. huttoniae* WRIGHT, 1878 in the synonymy of *M. adustus* LAMARCK. E. A. SMITH (1897) compared the holotype of *M. penchinati* CROSSE, 1861 in the British Museum (Natural History) with New Caledonian specimens of *M. huttoniae* WRIGHT, and found them to be identical in every respect.

### *Chicoreus capucinus* (RÖDING, 1798)

(Plate 14, Figure 7)

1791. *Murex ramosus* var.  $\gamma$  GMELIN (pars), Syst. Nat., ed. 13, p. 3528, no. 13 (non LINNAEUS, 1758)  
 1798. *Purpura capucina* RÖDING, Mus. Bolten., p. 143, no. 1797 (ref. Tour d'Auverg., [FAVANNE, 1784], 1073, and MARTINI, 1777, 3, t. 105, fig. 994)  
 1807. *Purpura brunnea* LINK (pars), Besch. Nat.-Samml. Univ. Rost., p. 121 (ref. MARTINI, *op. cit.*, figs. 993, 994 only)  
 1822. *Murex capucinus* LAMARCK, Hist. nat. anim. sans vert. 7: 164 (ref. CHEMNITZ, 1795, 11, t. 192, figs. 1849, 1850 — spec. juv., fide LAMARCK)  
 1914. *Murex permaestus* HEDLEY, Proc. Linn. Soc. New Sth. Wales, 39: 745 (nom. nov. pro *M. capucinus* auctt.)

**Shell:** Shell heavy and solid, uniformly blackish-brown in colour, whorls convex. Teleoconch consists of 6 whorls, protoconch of  $1\frac{1}{2}$  nuclear whorls. Sculptured with prominent spiral cords, intermediate lirae, axial riblets and striae; 3 varices per whorl and 2 axial nodes between varices; varices bluntly foliated. Aperture oviform, tinged with brown, labial lip with 14 to 17 prominent denticles; columella smooth, anal notch distinct. Siphonal canal broad, moderately short and slightly recurved, slit on ventral side open. Operculum with a basal nucleus.

**Size:** 45 mm to 60 mm.

**Type locality:** None. ("East Indies" fide MARTINI, 1777).

**Habitat:** Under coral rocks on muddy sand substratum, in shallow water. Rare.

**Distribution:** North Viti Levu. — From the Philippine Islands to North Australia and the Fiji Islands.

**Discussion:** The MARTINI (1777) figures 993 and 994 represent dorsal views of a dark brown shell resembling *Murex capucinus* of authors. The figured specimens were said to come from the East Indies and MARTINI further remarks that the specimen depicted in fig. 994 has slightly more frondose varices than the specimen illustrated in fig. 993. PFEIFFER (1840) assigns the figured species to *M. capucinus* LAMARCK. RÖDING (1798) clearly separated the frondose species of *Chicoreus* by placing them in the section "*Frondosae* — *Aestige*" while species of *Naquetia*

### Explanation of Plate 14

- Figure 1: *Murex trapa* RÖDING. x 0.8  
 Figure 2: *Murex tribulus* LINNAEUS. x 0.7  
 Figure 3: *Murex (Haustellum) haustellum* LINNAEUS. x 0.6  
 Figure 4: *Phyllocoma convolutum* (BRODERIP). x 2.6  
 Figure 5: *Chicoreus aculeatus* (LAMARCK). x 1.4  
 Figure 6: *Chicoreus brunneus* (LINK). x 0.6

Figure 11: *Chicoreus ramosus* (LINNAEUS). x 0.2

- Figure 7: *Chicoreus capucinus* (RÖDING). x 0.6  
 Figure 8: *Chicoreus carneolus* (RÖDING). x 0.6  
 Figure 9: *Chicoreus laciniatus* (SOWERBY). x 1.3  
 Figure 9a: *Chicoreus laciniatus* (SOWERBY). x 1.3  
 Figure 9b: *Chicoreus laciniatus* (SOWERBY). x 1.3  
 Figure 10: *Chicoreus microphyllus* (LAMARCK). x 1.4 & 1.2

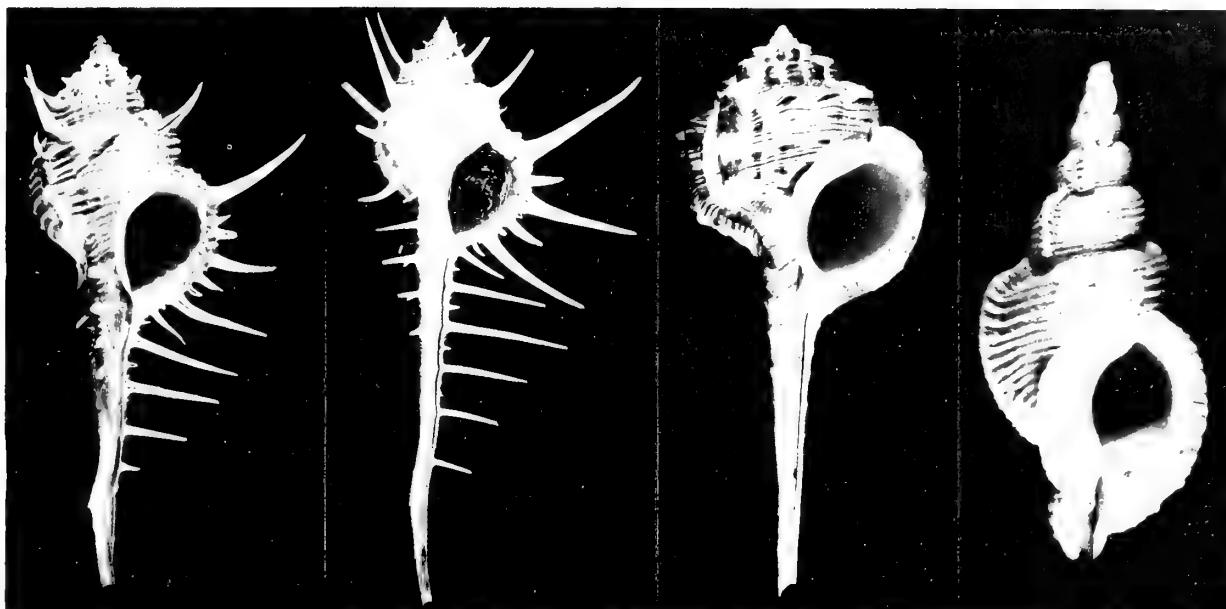


Figure 1

Figure 2

Figure 3

Figure 4

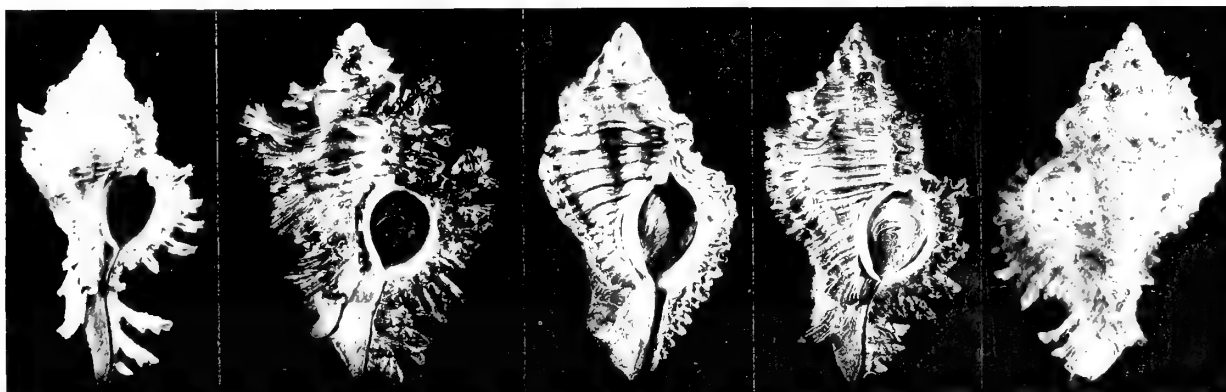


Figure 5

Figure 6

Figure 7

Figure 8

Figure 9

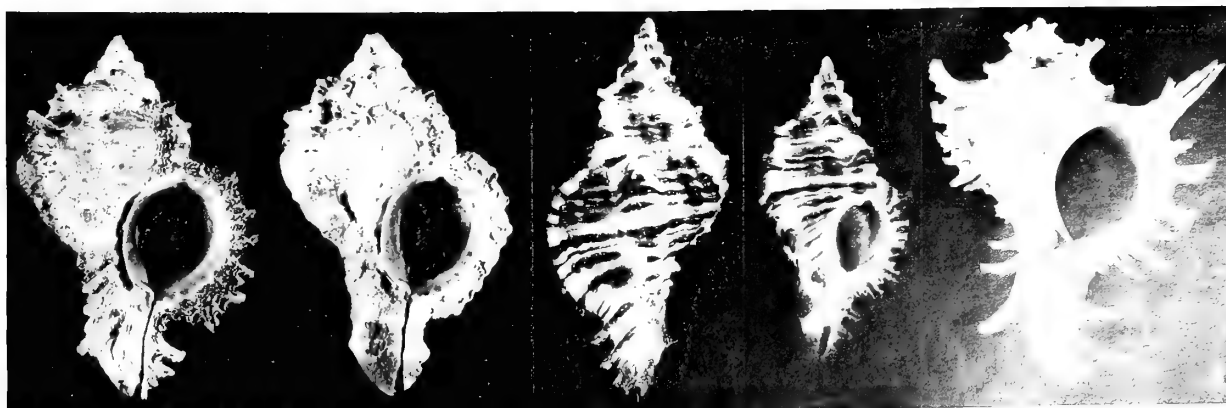


Figure 9 a

Figure 9 b

Figure 10

Figure 11



including *Purpura capucina* were placed under "*Optusae* – Abgestumpfte." RÖDING (*op. cit.*) appended a rather important diagnostic sentence after *P. capucina* "Kettenhörner mit stumpfen Nahten," a feature which identifies *P. capucina* in conjunction with the cited figures and MARTINI's text.

Recent writers assign *Murex capucinus* to *Naquetia* JOUSSEAU, 1880, in the genus *Pterynotus* SWAINSON. H. & A. ADAMS (1853) placed the species in *Chicoreus* MONTFORT, and this placing appears to be quite appropriate. The general features of the shell of the species resemble *Chicoreus* more than *Naquetia* or *Pterynotus*; varices are neither wing-like nor compressed, and blunt varices are evident in other *Chicoreus* species; the anal notch is distinct in *Chicoreus* but shallow or obsolete in *Pterynotus* or *Naquetia*.

*Chicoreus carneolus* (RÖDING, 1798)

(Plate 14, Figure 8)

1791. *Murex ramosus* GMELIN (pars), Syst. Nat., ed. 13, p. 3528, no. 13 (non LINNAEUS, 1758)  
 1798. *Purpura carneola* RÖDING, Mus. Bolten., p. 142, no. 1792 (ref. MARTINI, 1777, 3, t. 106, figs. 995, 996)  
 1807. *Purpura elongata* LINK, Besch. Nat.-Samml. Univ. Rost., p. 121 (ref. MARTINI, *op. cit.*, figs. 995, 996, 997) [non *Murex elongatus* LIGHTFOOT, 1786 = *Pterynotus* sp.]  
 1811. *Triplex abortiva* PERRY, Conchology, pl. 6, fig. 5  
 1841. *Murex torrefactus* SOWERBY, Conch. Illust., *Murex*, figs. 110, 111  
 1841. *Murex torrefactus* SOWERBY, Proc. Zool Soc. London for 1840; pt. 8: 141  
 1966. *Murex (Chicoreus) torrefactus* SOWERBY, CERNOHORSKY, The Veliger 8 (4): 231-233, 6 text figs. (radula and egg-capsules)

**Shell:** Shell solid and heavy, more slender than that of *Chicoreus brunneus* (LINK), uniformly dark brown in colour, spire elevated, whorls convex. Teleoconch of 7 whorls, protoconch with 2 orange-brown, smooth and bulbous nuclear whorls which are calcified in large specimens. Sculptured with gemmate spiral cords and close-set intermediate spiral ridges, 3 varices per whorl, and 1 to 2 nodes between varices. The frondose spines are moderately short on early whorls, but prominent on the labial varix and siphonal canal; this feature, however, is variable, and in some specimens the varical fronds are quite short. The labial varix has generally 5 primary and 5 secondary fronds, and the siphonal canal 3 frondose spines on the average. Aperture oviform, cream, orange or bluish-white in colour, deep interior white. Labial lip with 10 to 15 sharp denticles, columella smooth or occasionally with 1 to 3 denticles, anal notch distinct. Siphonal canal moderately produced, broad, slightly recurved, slit on ventral side open.

**Size:** 25 mm to 85 mm.

**Type locality:** None. The species has been reported from "Ostindien" by MARTINI (1777), and "Indonesia" is here designated as type locality.

**Habitat:** Under coral, on muddy sand substratum in shallow water. Common.

**Distribution:** Throughout the Fiji Islands. – From East Africa to Japan, East Australia and the Tuamotu Archipelago.

**Discussion:** The MARTINI figure 995 cited by RÖDING (1798) depicts the species *Murex torrefactus* SOWERBY and of authors. Figure 996 on the same plate is an immature specimen of the same species. The additional figure 997 cited by LINK (1807) is a white *Chicoreus* species with yellowish varices and is undeterminable.

It is unfortunate that an older and prior name has to be re-introduced into the literature in replacement for *Murex torrefactus* SOWERBY. Although both *Purpura carneola* RÖDING and *Triplex abortiva* PERRY could qualify as *nomina oblita* under the 50-year rule of the Code of ICZN (1964, art. 23b), *Purpura elongata* LINK does not. TOMLIN & WINCKWORTH (1936) drew attention to LINK's *P. elongata* which they rightly synonymized with *Murex torrefactus* SOWERBY. Even though *P. elongata* LINK is neither a primary nor a secondary homonym of *Murex elongatus* LIGHTFOOT (one is a *Chicoreus* species, the other a *Pterynotus* species), secondary homonymy could be introduced by writers assigning both species to *Murex* s. lat. In this particular case I thought it advisable to re-introduce RÖDING's prior name.

*Chicoreus laciniatus* (SOWERBY, 1841)

(Plate 14, Figures 9, 9 a, 9 b; Text figure 3)

1841. *Murex laciniatus* SOWERBY, Conch. Illust., *Murex*, fig. 59 (non DESHAYES & MILNE-EDWARDS, 1843)  
 1960. *Murex (Chicoreus) raciniatus* (sic) SOWERBY, AZUMA, Cat. Moll. Okin. Japan., p. 33, pl. 4, fig. 10

**Shell:** Shell moderately solid, orange-brown to greyish-brown in colour, spire elevated, whorls convex. Teleoconch of 6 to 7 whorls, protoconch of 1½ smooth nuclear whorls which are generally calcified in mature specimens. Sculptured with strong spiral cords, 3 varices per whorl, 2 nodes between varices and axial ribs on earlier whorls. The frondose spines are short or very short, numbering from 7 to 9 on the labial varix and 2 to 3 on the siphonal canal. Aperture moderately large, oviform, mauve in colour; labial lip with 12 to 17 denticles, columella smooth, anal notch moderately distinct. Siphonal canal moderately short and broad, slit on ventral side open. Operculum with a basal nucleus.

**Radula:** The radula (Text figure 3) is of the *Chicoreus* type, rhachidians with 3 main cusps and 2 only slightly

smaller intermediate cusps. The radular ribbon is 4.6 mm long and 0.22 mm wide in a shell 39 mm in length. The ribbon is translucent white and contains 182 rows of teeth (+ 7 nascentes).

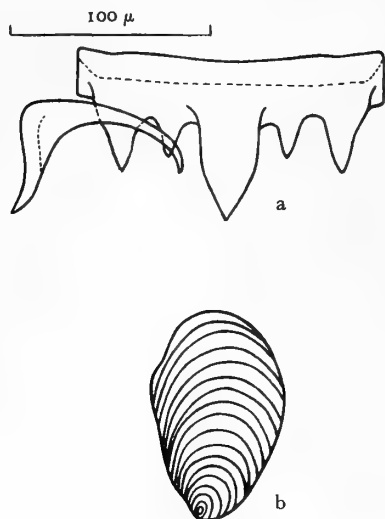


Figure 3

*Chicoreus laciniatus* (SOWERBY)

a. Half-Row of Radular Teeth

Fiji Islands

b. Operculum

**Size:** 32 mm to 45 mm.

**Type locality:** None. ("Les côtes de l'isle Aroë, mers du Japon," *vide* KIENER, 1843).

**Habitat:** Under coral, on sand and coral-rubble substratum from 0 to 5 fathoms. Rare.

**Distribution:** Mamanuca group, West off Viti Levu. — Philippine Islands, Japan.

**Discussion:** Fiji specimens have always a rose-purple or mauve coloured aperture, and conform in this feature with SOWERBY's illustration. Japanese specimens of *Murex laciniatus*, as figured by AZUMA (1960), HASE (1961) and D'ATTILIO (1966) show the aperture to be either white or cream.

The varical fronds are short or even blunt in this species, a feature which may prompted some writers to assign this species to *Naquetia* JOUSSEAUME. The species *Chicoreus microphyllus* (LAMARCK) has also degenerate fronds or spines, as do some specimens of *C. carneolus* (RÖDING); it would appear that the length of fronds or spines is a rather variable feature and an unreliable character for generic assignment.

*Chicoreus microphyllus* (LAMARCK, 1816)

(Plate 14, Figure 10; Text figure 4)

1816. *Murex microphyllus* LAMARCK, Tabl. Encycl. Méth., p. 4, pl. 415, fig. 5

1833. ? *Murex rubescens* BRODERIP, Proc. Zool. Soc. London for 1832, pt. 1: 174

1881. *Chicoreus poirieri* JOUSSEAUME, Le Naturaliste, 2 (42): 349 (New Caledonia)

**Shell:** Shell moderately solid, white to cream in colour, ornamented with blackish-brown cords and patches on varices. Teleoconch of 7 whorls, protoconch with  $1\frac{1}{2}$  smooth nuclear whorls. Sculptured with strong spiral cords, fine intermediate spiral lirac and 3 varices per whorl; varical fronds degenerate, appearing as short foliations, numbering from 5 to 7 on the labial varix and from 2 to 3 on the siphonal canal. Aperture moderately small, cream in colour, labial lip with 10 to 15 denticles, columella with 13 to 15 small denticles, anal notch prominent. Siphonal canal moderately slender, slit on ventral side open. Operculum (Text figure 4) orange-brown and with a basal nucleus.



Figure 4

Operculum of *Chicoreus microphyllus* (LAMARCK)

**Size:** 30 mm to 43 mm.

**Type locality:** None. ("Tahiti," *vide* BRODERIP, 1833).

**Habitat:** Under coral rock, on clean sand substratum, from 0 to 3 fathoms. Rare.

**Distribution:** North Viti Levu. — From the Seychelles Islands to Japan, East Australia and the Society Islands.

**Discussion:** *Chicoreus microphyllus* differs from other members of the genus in features of blunt varices and denticulate columella. These two characters seem to be rather variable and appear in species of the genera *Chicoreus*, *Pterynotus* and *Haustellum*.

*Chicoreus ramosus* (LINNAEUS, 1758)

(Plate 14, Figure 11; Text figure 5)

1758. *Murex ramosus* LINNAEUS (pars), Syst. Nat., ed. 10, p. 747, no. 488 (RUMPHIUS, 1705, t. 26, fig. A — first correct ref.)

1798. *Purpura ramosa* var.  $\alpha$  RÖDING, Mus. Bolten., p. 142, no. 1786 (ref. MARTINI, 1777, 3, t. 103, figs. 981, 982)  
 1798. *Purpura incarnata* RÖDING, Mus. Bolten., p. 142, no. 1791 (ref. MARTINI, *op. cit.*, t. 102, figs. 980 & t. 103, fig. 981)  
 1822. *Murex inflatus* LAMARCK, Hist. nat. anim. sans vert., 7: 160 (ref. MARTINI, *op. cit.*, figs. 980, 981)  
 1825. *Murex monodon* (pars) SOWERBY, Cat. shells coll. Tank., App. p. 19 (ref. MARTINI, *op. cit.*, fig. 980 only)  
 1852. *Murex frondosus* MÖRCH, Cat. conch. Yoldi, 1: 97 (non *Triplex frondosus* PERRY, 1811 = *Chicoreus* sp.)

**Shell:** Shell large and solid, white or creamy-white in colour, ornamented with brown spiral lines and occasional brown patches near sutures. Teleoconch consists of 6 to 7 whorls, protoconch generally calcified. Sculptured with a few strong spiral cords, numerous fine spiral lirae and 1 to 2 nodes between varices; varices number 3 per whorl or 4 varices on earlier whorls. Varical fronds moderately produced, foliated, open and recurved; labial varix with 6 to 10 fronds, siphonal canal with 2 to 3. Aperture large,

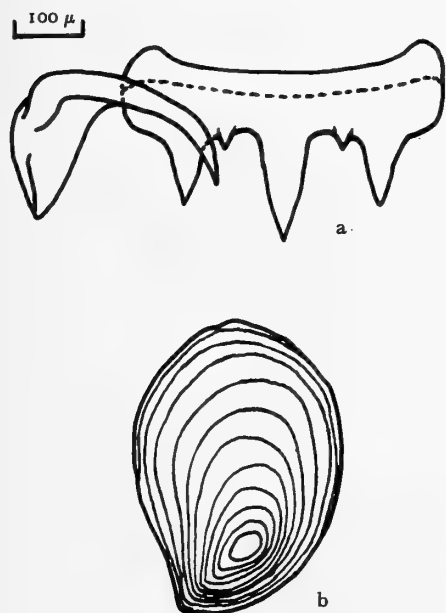


Figure 5

*Chicoreus ramosus* (LINNAEUS)

a. Half-Row of Radular Teeth

b. Operculum

Fiji Islands

roundly ovate, rosy-red on periphery, white in interior. Labial lip with 11 to 17 denticles, fifth denticle anteriorly of the siphonal canal larger than others; columella smooth, anal notch prominent. Siphonal canal broad and recurved, slit on ventral side open. Operculum with sub-basal nucleus.

**Radula:** Radular ribbon (Text figure 5) is 24.0 mm long and 0.80 mm wide in an animal with a shell 216 mm in length. The ribbon contains 215 rows of teeth (+ 13 nascentes); rhachidians equipped with 3 main cusps and 2 rather small intermediate denticles.

**Size:** 100 mm to 230 mm.

**Type locality:** In Sinu Persico, Jamaica; (latter locality erroneous).

**Habitat:** On coral reefs, on clean sand substratum, from 0 to 5 fathoms. Moderately common.

**Distribution:** Throughout the Fiji Islands. — From the Red Sea to Japan, East Australia and Samoa.

**Discussion:** *Murex ramosus* LINNAEUS is such a badly conceived species that it is questionable whether it can be retained in muricid nomenclature either as a species or a type species. From the 16 figures cited by LINNAEUS (1758) for *M. ramosus*, only 2 or possibly 3 figures depict *M. ramosus* auctt.; the citations cover 7 different species. GMELIN (1791) and DILLWYN (1817) adopted the same confused synonymy. RÖDING (1798) cited MARTINI (1777), figures 981 and 982 for *Purpura ramosa* var.  $\alpha$ ; the figures cited represent *Murex ramosus* auctt. and *M. brevifrons* LAMARCK, 1822 respectively. *Purpura ramosa* LINK, 1807 is identical with RÖDING's species. The *M. ramosus* of MONTFORT, 1810, generally cited as the type of *Chicoreus* MONTFORT, 1810 is *M. brevifrons* LAMARCK. *Murex inflatus* LAMARCK, 1822 is *M. ramosus* auctt. and is an objective synonym of *P. incarnata* RÖDING, 1798 and a primary homonym of *M. inflatus* BROCCHE, 1814.

*Murex ramosus* of authors will have to remain a species without a holotype since the Linnean collection contains 2 syntypes of *M. ramosus* LINNAEUS, one of which is the species *M. pomum* GMELIN, 1791 and the other *M. brunneus* (LINK, 1807); both specimens appear to be genuine syntypes as both were marked in Linnaeus' handwriting for *M. ramosus* (fide DODGE, 1957). Neither of the two syntypes would qualify for a lectotype selection of *M. ramosus* auctt., and a re-introduction of *Purpura incarnata* RÖDING, 1798 for the large Indo-Pacific *Chicoreus* species may prove to be the most acceptable course in the circumstances.

On the basis of cited figures, *Murex monodon* SOWERBY, 1825 is *M. ramosus* LINNAEUS in part only. SOWERBY (1825) refers to "Martini [1777], Conch. Cab., 3, t. 105, figs. 987, 980" for *M. monodon*; figure 987 is *M. monodon*, figure 980 is *M. ramosus*. However, figure 980 does not occur on plate 105 but on plate 102, and it is therefore probable that figure 980 is a transcription error for figure 988 on plate 105, which is indeed *M. monodon*. *Purpura cornucervi* RÖDING, 1798, was based on the same figures 987 and 988, and has priority.

*Chicoreus saulii* (SOWERBY, 1841)

(Plate 15, Figure 12)

1841. *Murex saulii* SOWERBY, Conch. Illust., *Murex*, fig. 77  
 1841. *Murex saulii* SOWERBY, Proc. Zool. Soc. London for 1840, pt. 8: 141  
 1853. *Murex (Chicoreus) sauliae* (sic) SOWERBY, H. & A. ADAMS, Gen. Rec. shells, 1: 73  
 1896. *Murex saulae* (sic) SOWERBY, CROUCH, Proc. Malac. Soc. London, 2 (3): 135  
 1959. *Murex (Chicoreus) saulii* (sic) SOWERBY, KIRA, Col. illust. shells Japan, 1: 189, pl. 69, fig. 1

**Shell:** Shell moderately light in weight, orange-brown in colour, ornamented with dark brown spiral cords. Teleoconch consists of 7 to 8 whorls, protoconch with  $1\frac{1}{2}$  brown and smooth nuclear whorls. Sculptured with spiral cords and fine, gemmate intermediate spiral lirae, 1 to 2 nodes between varices which number 3 per whorl. Varical fronds moderately produced, foliated and open, numbering from 4 to 6 on the labial varix and 2 to 3 on the siphonal canal. Aperture moderately large, white in colour, occasionally with a light rosy tinge; labial lip with 13 to 18 denticles, columella smooth, but occasionally with a single denticle near the siphonal canal; anal notch prominent. Siphonal canal moderately slender and produced, slit on ventral side open.

**Size:** 64 mm to 75 mm.

**Type locality:** Insulam Capul, Philippinarum.

**Habitat:** Dredged in 8 fathoms on coral-rubble substratum. Rare.

**Distribution:** South Viti Levu. — From the Philippine Islands to Japan, East Australia and the Fiji Islands.

**Discussion:** As is evident from the synonymy, this specific name is frequently misspelled, due no doubt to SOWERBY's unusual latinization of a patronymic name. Miss Jane Saul had 8 species named in her honour which were spelled either "*saulae*" or "*sauliae*." SOWERBY named 2 of these, one which he spelled *Murex saulii* while he spelled the other *Marginella sauliae* SOWERBY, 1846, although both species originated from the same collection.

*Pterynotus* SWAINSON, 1833

*Pterynotus* SWAINSON, 1833, Zool. Illust., ser. 2, pl. 100 — Type species by SD (SWAINSON, 1833) *Murex pinnatus* SWAINSON, 1822 = *Pterynotus alatus* (RÖDING, 1798)

**Characters:** Shell light in weight, slender, spire high, whorls convex. Sculptured with numerous fine spiral cords, axial riblets in interstices, thin, compressed and incised varices, 3 varices per whorl and nodes between varices; varical spines or fronds absent in the type species, but may appear as curved hook-like appendages in other members of the genus. Aperture small, elongate-ovate, labial

lip denticulate, columella generally smooth, anal notch weak. Siphonal canal slender, produced and recurved, slit on ventral side open.

Operculum with a basal nucleus. The rhachidians of the radula are equipped with 3 large, almost equal-sized main cusps, while intermediate denticles are absent (*vide* HABE in VOKES, 1964).

**Discussion:** The type species *Murex pinnatus* SWAINSON was no stranger to 18th century iconographers. MARTINI (1777) describes in detail his "geflügelte dreieckige Purpurschnecke" and figures the species on plate 111, figures 1036 and 1037. These figures are unquestionably *Murex pinnatus* and were cited by RÖDING (1798) for *Purpura alata* ("The white winged Purpura snail" [trans.]). The synonymy of *M. pinnatus* SWAINSON appears to be as follows:

1791. *Murex ramosus* var. *e* (pars) GMELIN, Syst. Nat., ed. 13, p. 3528, no. 13 (non LINNAEUS, 1758)  
 1798. *Purpura alata* RÖDING, Mus. Bolten., p. 144, no. 1085 (ref. MARTINI, 1777, 3, t. 111, figs. 1036, 1037)  
 1822. *Murex pinnatus* SWAINSON, Cat. coll. Bligh, App. p. 17 (non *Triplex pinnata* PERRY, 1811 = *Pterynotus* sp.)  
 1840. *Murex martinianus* PFEIFFER, Krit. Reg. Mart. & Chemn., p. vii (ref. MARTINI, *op. cit.*, figs. 1036, 1037) [non REEVE, 1845]

PFEIFFER (1840) in his critical analysis of MARTINI & CHEMNITZ's "Conchylien-Cabinet" remarks that he could elucidate the species illustrated in the first four volumes through the study of Martini's original specimens; the labels were marked in Martini's own handwriting and were in the Museum of Pfeiffer's brother-in-law, Mr. Hermann Nathusius of Hundisburg. Pfeiffer considered the species figured by MARTINI (*op. cit.*) in figures 1036 and 1037 as undescribed, overlooking RÖDING's prior description. DESHAYES & MILNE-EDWARDS (1843) as well as DUNKER (1882) refer the MARTINI figures 1036 and 1037 to the synonymy of *Murex pinnatus* SWAINSON.

Not only is *Pterynotus alatus* (RÖDING) an earlier name for *Murex pinnatus*, but SWAINSON's species name may well be a secondary homonym of *Triplex pinnata* PERRY, 1811 (plate 7, figure 5). PERRY's figure represents a white *Pterynotus* species which has been synonymized, possibly incorrectly, with *M. tripterus* BORN, 1778 by DESHAYES & MILNE-EDWARDS (1843, p. 578). *Murex phyllopterus* LAMARCK, 1822, described from an unknown locality and without figure citations, is almost certainly *M. pinnatus*; the description fits the species perfectly.

*Murex alatus* GMELIN, 1791 (based on CHEMNITZ, 1780, 4, t. 159, figs. 1503, 1504) does not pre-occupy *Purpura alata* RÖDING, 1798, as GMELIN's species is a clavinine turrid better known as *Pleurotoma crenulata* LAMARCK, 1822.

No type locality has been cited by RÖDING (1798) for his *Purpura alata*; however, MARTINI (1777, p. 349) reports the species from the coast of Coromandel, Tranquebar [= Tranquebar, southeast coast of India].

*Pterynotus elongatus* (LIGHTFOOT, 1786)

(Plate 15, Figure 13)

1786. *Murex elongatus* LIGHTFOOT, Cat. Port. Mus., p. 65, no. 1479 (ref. FAVANNE, 1780, pl. 79, fig. H)  
 1791. *Murex ramosus* var.  $\varepsilon$  (pars) GMELIN, Syst. Nat., ed. 13, p. 3528, no. 13 (non LINNAEUS, 1758)  
 1798. *Purpura draco* RÖDING, Mus. Bolten., p. 144, no. 1809 (ref. MARTINI, 1777, 3, fig. 1033)  
 1822. *Murex uncinarius* LAMARCK, Hist. nat. anim. sans vert., 7: 166 (ref. MARTINI, *op. cit.*, t. 111, figs. 1034 ?, 1035 ?)  
 1842. *Murex clavus* KIENER, Spéc. Gen. Icon. Coq. Viv., *Murex*, pp. 111-112, pl. 37, figs. 2, 2 (ref. MARTINI, *op. cit.*, t. 111, figs. 1033, 1034, 1035) [non MICHELOTTI, 1841]  
 1967. *Murex elongatus* SOLANDER, CROSS, Hawai. Shell News, 15 (1) : 1, 2 figs. (animal)

**Shell:** Shell light in weight, white or creamy-white in colour throughout; spire very long and slender, whorls convex. Teleoconch consisting of 7 whorls, protoconch calcified in adult specimens. Sculptured with spiral striae which are close-set and prominent on varices, granulose spiral cords at base and 3 wing-like, thin and compressed varices at every whorl; earlier whorls axially ribbed between varices. Fronds or spines generally absent, but some specimens do have a few curved, open and hook-like varical appendages. Aperture small, elongate-ovate, white or creamy-white, sometimes with a pinkish tinge; labial lip with 15 to 20 denticles, columella elevated and with 2 to 4 denticles situated near the siphonal canal, anal notch obsolete. Siphonal canal moderately broad and short, slit on ventral side open.

**Size:** 55 mm to 70 mm.

**Type locality:** None. "Ostindien, Batavia" was mentioned as locality by MARTINI (1777) and "Batavia, Indonesia" is here selected as type locality.

**Habitat:** On coral and clean sand substratum, from 3 to 5 fathoms. Rare.

**Distribution:** Throughout the Fiji Islands. — From the Red Sea to Japan, North Australia and the Hawaiian Islands.

**Discussion:** MARTINI's figure 1033 was based on a specimen from the Bolten collection (*vide* MARTINI, 1777, p. 349); the same specimen was later named *Purpura draco* RÖDING, 1798, and the same figure 1033 has been referred to by KIENER (1843) for his *Murex clavus*. MARTINI (*op. cit.*) figured another specimen of *M. elongatus* on the same plate in figures 1034 and 1035. The figured specimen, which appears to be beach-worn (labial lip is missing)

has been described in detail by MARTINI; the author mentioned the three-sided appearance of the shell and the 3 compressed varices as well as the shell's fragile texture. He went on to point out that the actual shell was larger than depicted in the figure (ca. 56.0 mm). These 2 figures, however, were cited with a query for *M. uncinarius* LAMARCK, 1822, for which a size of 11 lignes (ca. 25.0 millimeters) was given. On the basis of LAMARCK's figure citations, *M. uncinarius* is unquestionably conspecific with *M. elongatus* LIGHTFOOT; his description also agrees with the latter species, with the exception of the phrase "albido-fulva" and the small size of LAMARCK's specimen. *Murex uncinarius* KIENER, 1842 and of authors is a small muricid species from South Africa, and is the type species of *Poropteron* JOUSSEAUME, 1880. This is once again a case where cited figures are in conflict with the subsequent interpretation of the species and possibly the holotype. The only possibility of evaluating *M. uncinarius* LAMARCK is to figure and re-describe the holotype, and expunge the cited MARTINI figures from the synonymy, provided that LAMARCK's species is indeed conspecific with KIENER's *M. uncinarius*. Another alternative would be to accept the subsequent junior synonym *M. capensis* SOWERBY, 1841 (Conch. Illust., fig. 76). SOWERBY's *M. mitraeformis* (1841, fig. 75) has figure priority, but is a homonym of *M. mitraeformis* BROCCHI, 1814.

*Murex clavus* MICHELOTTI, 1841 need not be replaced on account of the earlier *M. clava* GMELIN, 1791. The Latin words *clāva* and *clāvus* are nouns of feminine and masculine gender respectively, and the rule of adjectival species-group names does not apply in this case.

KIENER's plates to *Murex* were issued in 1842 (*vide* SHERBORN & WOODWARD, 1901, p. 217) and the text in 1843. The plates contain the specific names at the lower margin and KIENER's *Murex* species have been established as from the date of issue of the plates.

(*Naquetia*) JOUSSEAUME, 1880

*Naquetia* JOUSSEAUME, 1880, Le Naturaliste, 2 (42) : 335 — Type species by OD *Murex triqueter* BORN, 1778

**Characters:** Shell solid, moderately slender, spire elevated, whorls convex. Sculptured with coarse spiral cords, axial ribs and 3 varices per whorl; varices are not wing-like and compressed as in *Pterynotus*, and flat flanges are evident on the labial varix. Aperture oviform, labial lip denticulate, columella smooth or denticulate, anal notch shallow or obsolete. Siphonal canal broad and moderately short.

Operculum with a basal nucleus. The rhachidians of the radula are broad and short, with only 3 cusps of

which the central cusp is twice as long as the side-cusps; intermediate cusps are degenerate, indicated only as vertically incised wrinkles in some specimens, or are absent altogether in other specimens.

**Discussion:** In shell and radula characters, this group is intermediate between *Chicoreus* MONTFORT and *Pterynotus* SWAINSON. The radula, although similar in characters to *Pterynotus* (vide HABE in VOKES, 1964), differs sufficiently to separate the group at least subgenerically. The 3 main cusps in *Pterynotus* are large and almost of equal size, and rather similar in pattern to the radula of *Typhis tosaensis* AZUMA, 1960 (p. 99, text fig. 2). In *Naquetia*, however, the main central cusp is twice as long as the flanking main cusps, and remnants of the small intermediate denticles may occasionally be seen in some specimens.

*Pterynotus (Naquetia) tripterus* (BORN, 1778)  
(Plate 15, Figure 14)

1778. *Murex tripterus* BORN, Ind. rer. nat. Mus. Caes. Vindob., p. 287  
1780. *Murex tripterus* BORN, Test. Mus. Ces. Vindob., p. 291, t. 10, figs. 18, 19  
1834. ? *Murex trialatus* var. SOWERBY, Conch. Illust., *Murex*, fig. 54 only

**Shell:** Shell solid and heavy, dirty-white or light fawn in colour throughout. Teleoconch consists of 5 to 6 whorls, protoconch with 2 calcified nuclear whorls. Sculptured with spiral ridges, 3 varices per whorl and a single node between varices; labial varix large and compressed. Aperture elongate-oviform, flesh or cream in colour, labial lip with 6 to 8 white denticles and small accessory denticles; columella with 7 to 10 white denticles, anal notch obsolete. Siphonal canal broad and short, slit on ventral side open. Operculum orange-brown and with a sub-basal nucleus.

**Size:** 30 mm to 60 mm.

**Type locality:** Coasts of Batavia.

**Habitat:** Under coral rocks, on muddy sand substratum, in shallow water. Rare.

**Distribution:** West Viti Levu. — From Indonesia to Japan and the Fiji Islands.

**Discussion:** DESHAYES & MILNE-EDWARDS (1843, p. 578)

place *Triplex pinnata* PERRY, 1811 in the synonymy of *Murex tripterus* BORN. PERRY's figure does not quite resemble *M. tripterus*, unless it be a very worn specimen.

*Pterynotus (Naquetia) triquetter* (BORN, 1778)  
(Plate 15, Figure 15; Text figure 6)

1778. *Murex triquetter* BORN, Ind. rer. nat. Mus. Caes. Vindob., p. 288  
1780. *Murex triquetter* BORN, Test. Mus. Caes. Vindob., p. 291, t. 11, figs. 1, 2  
1791. *Murex ramosus* var.  $\xi$  (pars) GMELIN, Syst. Nat., ed. 13, p. 3528, no. 13 (non LINNAEUS, 1758)  
1798. *Purpura variegata* RÖDING, Mus. Bolten., p. 143, no. 1799 (ref. MARTINI, 1777, 3, t. 111, fig. 1038)  
1798. *Purpura cancellata* RÖDING, Mus. Bolten., p. 143, no. 1801 (ref. MARTINI, op. cit., t. 111, fig. 1038)  
1811. *Triplex flexuosa* PERRY, Conchology, pl. 7, fig. 1  
1816. *Murex trigonulus* LAMARCK, Tabl. Encycl. Méth., p. 5, pl. 417, figs. 4 a, 4 b  
1907. *Murex (Chicoreus) triquetter* var. *amanuensis* COUTURIER, Journ. Conchyl., 55: 142

**Shell:** Shell moderately light in weight but solid, spire elevated; uniformly creamy-white or light brown, maculated with dark brown on varices and labial lip. Teleoconch consists of 5 to 6 whorls, protoconch with 2 smooth brown nuclear whorls. Sculptured with spiral cords and intermediate spiral ridges, 3 varices per whorl and 2 to 3 axial ribs between varices; varices foliated and somewhat compressed anteriorly. Aperture moderately small, oviform and white, labial lip with 12 to 16 denticles; columella smooth, occasionally with a denticle near the siphonal canal, anal notch obsolete. Siphonal canal broad and short, or moderately slender and slightly produced, slit on ventral side open. Operculum with a basal nucleus.

**Radula:** The radula is of the *Pterynotus* type, with 3 main cusps only, but occasionally with extremely weak vestiges of intermediate denticles which do not protrude past the top of the plate. Length of radular ribbon 6.3 mm, width 0.31 mm in an animal with a shell 58 mm in length; the ribbon is white and numbers 102 rows of teeth (+ 6 nascentes) (see Text figure 6).

**Size:** 40 mm to 70 mm.

**Type locality:** None. ("Tranquebar, Ostindien," MARTINI, 1777).

### Explanation of Plate 15

- Figure 12: *Chicoreus saulii* (SOWERBY). x 0.7  
Figure 13: *Pterynotus elongatus* (LIGHTFOOT). x 0.9  
Figure 14: *Pterynotus tripterus* (BORN). x 0.9  
Figure 15: *Pterynotus triquetter* (BORN). x 0.9

Figure 20: *Favartia tetragona* (BRODERIP). x 1.5

- Figure 16: *Homalocantha anatomica* (PERRY). x 0.9  
Figure 17: *Poirieria nodulifera* (SOWERBY). x 0.9  
Figure 18: *Vitularia miliaris* (GMELIN). x 1.9 & 0.8  
Figure 19: *Favartia brevicula* (SOWERBY). 2.0

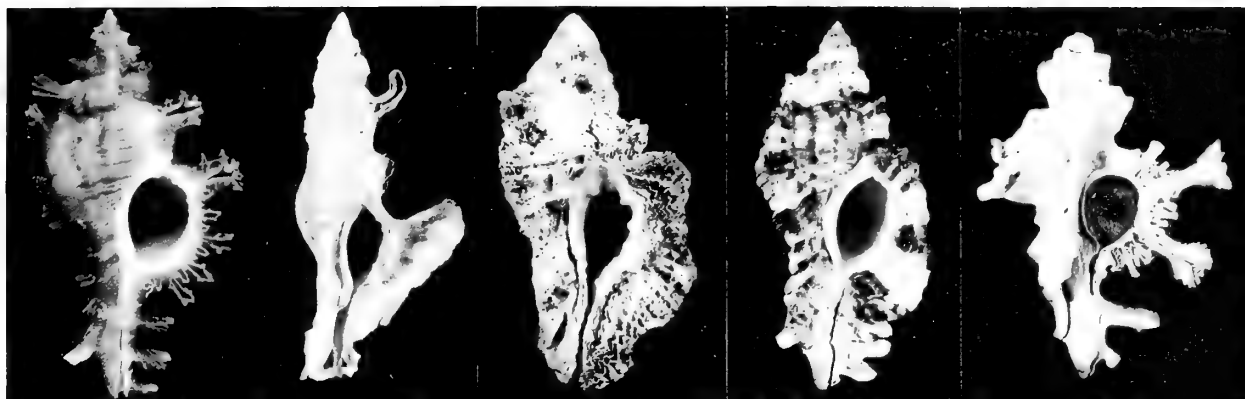


Figure 12

Figure 13

Figure 14

Figure 15

Figure 16

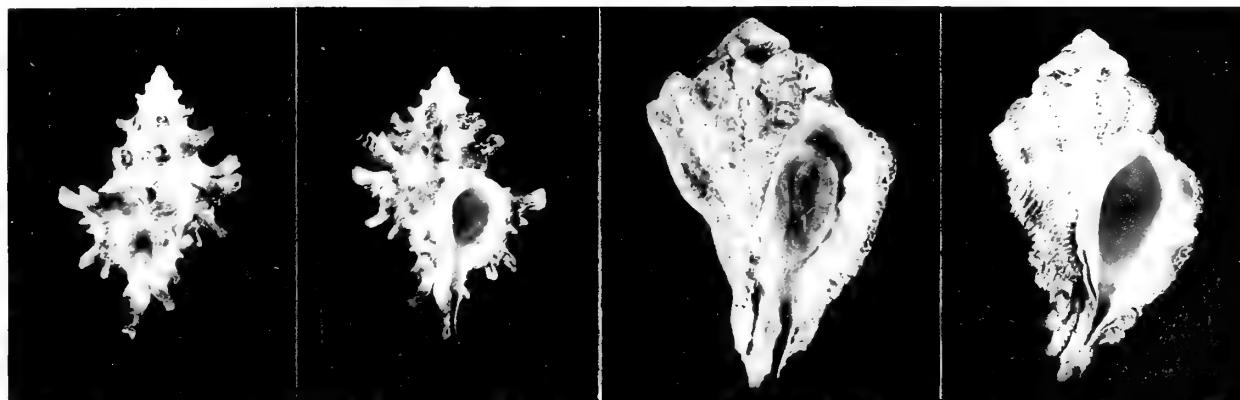


Figure 17

Figure 18

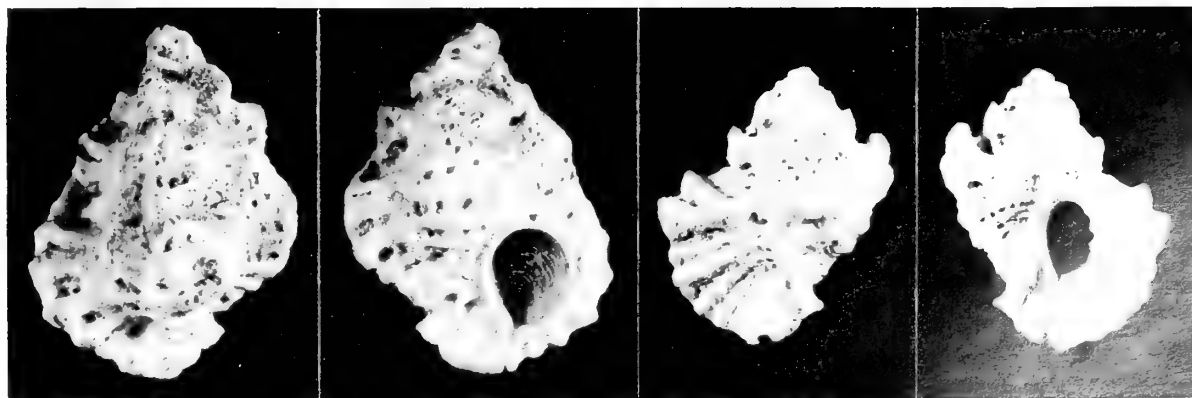


Figure 19

Figure 20



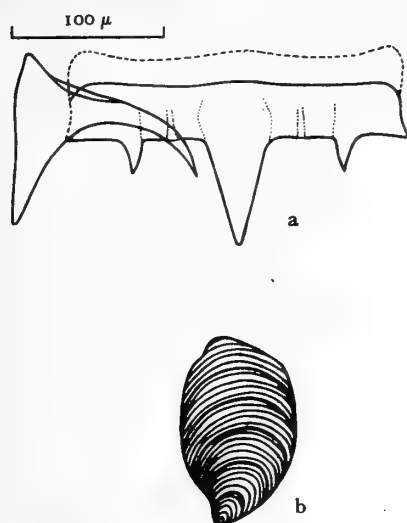


Figure 6  
*Pterynotus triqueter* (BORN)

a. Half-Row of Radular Teeth

Fiji Islands

b. Operculum

**Habitat:** Under coral rocks, on clean and muddy sand substratum, in shallow water. Uncommon.

**Distribution:** Throughout the Fiji Islands. — From East Africa to Japan, East Australia and the Tuamotu Archipelago.

**Discussion:** The type figures of *Murex trigonulus* LAMARCK, 1816, clearly depict *M. triqueter* BORN; six years later LAMARCK himself placed the species in the synonymy of *M. triqueter* BORN.

*Murex triqueter amanuensis* COUTURIER appears to be a smaller, more slender and elongated variant which occurs sporadically in Fiji and the Philippine Islands, and is of no racial significance.

*Poirieria* JOUSSEAU, 1880  
(Text figure 7)

*Poirieria* JOUSSEAU, 1880, Le Naturaliste, 2 (42): 335 — Type species by OD *Murex zelandicus* QUOY & GAIMARD, 1833

**Characters:** Shell light in weight, spire elevated, whorls angulate, varical spines moderately long and open, but becoming progressively shorter towards early whorls. Sculptured with weak spiral ridges and 5 to 6 varices per whorl. Aperture wide and oval, labial lip with foliated depressions, columella smooth and calloused, anal notch obsolete. Siphonal canal moderately long, open and recurved. Operculum with a basal nucleus.

**Discussion:** The radula of the type species *Poirieria zelandica* is figured here (Text figure 7). The radula was extracted from a specimen collected off Mayor Island, Bay of Plenty, New Zealand in 1926, and the slide was made available by Dr. A. W. B. Powell. The radular ribbon measured 6.7 mm in length and 0.24 mm in width, length of shell unknown; the radular ribbon contained 182 rows of teeth, and no nascentes were visible.

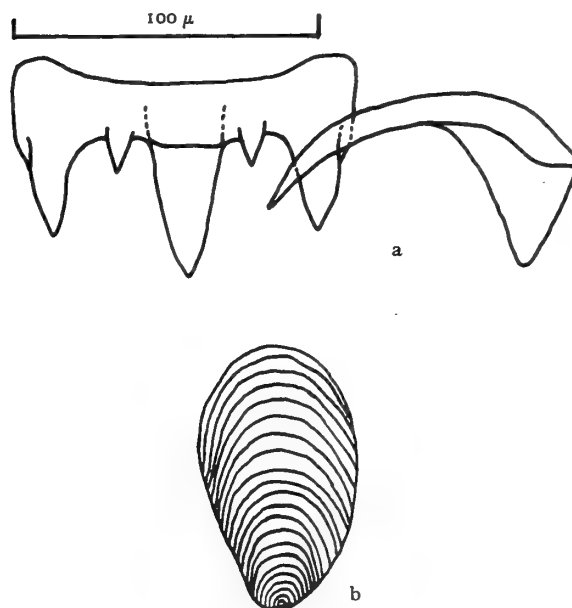


Figure 7

*Poirieria zelandica* (QUOY & GAIMARD)

a. Half-Row of Radular Teeth

b. Operculum

New Zealand

*Poirieria nodulifera* (SOWERBY, 1841)  
(Plate 15, Figure 17)

1841. *Murex noduliferus* SOWERBY, Conch. Illust., *Murex*, fig. 101

1841. *Murex noduliferus* SOWERBY, Proc. Zool. Soc. London for 1840, pt. 8: 147

**Shell:** Shell small and light in weight, spire elevated; creamy-white to yellowish in colour, irregularly lined with brown, varical spines and siphonal canal stained brown. Sculptured with spiral ridges, 6 to 7 varices on body whorl and 7 to 9 varices on earlier whorls; varical spines prominent and open, numbering from 4 to 6 on the labial varix and from 0 to 1 on the siphonal canal. Aperture oviform, white or creamy-yellow, labial lip with 5 to 7 denticles; columella smooth and calloused, occasionally

with 0 to 4 denticles near the siphonal canal, anal notch obsolete. Siphonal canal slender, moderately long, open and recurved.

**Size:** 20 mm to 32 mm.

**Type locality:** Insulam Masbate [Philippine Islands].

**Habitat:** On sand and coral-rubble substratum in 8 fathoms. Moderately rare.

**Distribution:** North and South Viti Levu. – From the Philippine Islands to Japan, New Guinea and the Fiji Islands.

**Discussion:** SHIKAMA (1963) assigned the species to the subfamily Drupinae, genus *Drupa* RÖDING, 1798, subgenus *Morula* SCHUMACHER, 1817, but I believe that a placing of this species in *Poirieria* is more appropriate. This species has an elevated spire, not unlike the type species of *Murexsul* IREDALE, 1915, and the denticulate labial lip is a character evident in *Muricopsis* BUCQUOY, DAUTZENBERG & DOLLFUS, 1882. The number of varices, produced and open varical spines and features of siphonal canal are characters associating the species with *Poirieria* JOUSSEAUME.

#### *Favartia* JOUSSEAUME, 1880

*Favartia* JOUSSEAUME, 1880, Le Naturaliste, 2 (42): 335 – Type species by OD *Murex breviculus* SOWERBY, 1834

**Characters:** Shell small and solid, teleoconch with about 5 whorls, protoconch with  $1\frac{1}{2}$  bulbous nuclear whorls. Sculptured with strong spiral cords and descending axial ridges which appear on varices as deep pits; varices strong and rounded, numbering 4 per whorl. Aperture roundly ovate, elevated, labial lip scalloped, columella smooth, anal notch absent. Siphonal canal short, recurved and either slightly open or completely closed in adult specimens.

Operculum is muricine, orange-brown in colour and with a basal nucleus. The radula type is muricine(?) (*vide* THIELE, 1929).

**Discussion:** VOKES (1964) placed *Favartia* in the genus *Aspella* and remarked that the group was intermediate between Muricinae and Tritonaliinae on account of the operculum which is muricine and a radula which is closer to Tritonaliinae. The operculum is undoubtedly muricine, and the radula of *Aspella* was described as muricine by THIELE (*op. cit.*), i. e. "rhachidian of radula with triangular central cusp and two smaller denticles between the three main cusps" [transl.]. *Favartia*, however, may not be related to *Aspella* at all, especially if the radulae of the two genera could be compared. *Favartia*, and especially the species *F. tetragona* (BRODERIP), bears a resemblance to *Nothotyphis* FLEMING, 1962, in features of shell appearance, size, latticed sculpture, guttered spines and completely closed canal.

#### *Favartia brevicula* (SOWERBY, 1834)

(Plate 15, Figure 19; Text figure 8)

1834. *Murex breviculus* SOWERBY, Conch. Illust., *Murex*, fig. 37

1841. *Murex breviculus* SOWERBY, Proc. Zool. Soc. London for 1840, pt. 8: 146

**Shell:** Shell small and solid, dirty-white in colour, whorls convex. Teleoconch consisting of 5 whorls, protoconch with  $1\frac{1}{2}$  bulbous calcified nuclear whorls. Sculptured with 5 to 6 strong spiral cords which are intersected by descending axial ridges which are especially prominent on varices; varices generally blunt and rounded, numbering 4 per whorl, and ornamented with 1 to 2 short spines. Aperture roundly-ovate, elevated, white, deep interior purplish; labial lip with 6 to 11 scalloped denticles, columella white, calloused and smooth, anal notch absent. Siphonal canal short and slender, slightly open or com-



Figure 8

Operculum of *Favartia brevicula* (SOWERBY)

pletely closed in adult specimens, and recurved almost at 90° towards the dorsum. Operculum orange-brown and with a basal nucleus (Text figure 8).

**Size:** 15 mm to 30 mm.

**Type locality:** None.

**Habitat:** Under coral rocks, on muddy sand and coral substratum in shallow water. Moderately common.

**Distribution:** Throughout the Fiji Islands. – From the Philippine Islands to Japan, East Australia and Tonga Islands.

**Discussion:** The siphonal canal is more slender and sharply recurved in *Favartia brevicula* than in *F. tetragona*. The siphonal canal is either slightly open or completely closed in adult specimens.

#### *Favartia tetragona* (BRODERIP, 1833)

(Plate 15, Figure 20)

1833. *Murex tetragonus* BRODERIP, Proc. Zool. Soc. London for 1832, pt. 1: 174

1834. *Murex tetragonus* BRODERIP, SOWERBY, Conch. Illust., *Murex*, fig. 25

**Shell:** Shell small and solid, white in colour throughout. Teleoconch consisting of 4 whorls, protoconch of  $1\frac{1}{2}$  nuclear whorls. Sculptured with 8 to 10 spiral cords, obsolete and irregular axial riblets and pittings in interstices of cords; varices number 4 per whorl, and are large and compressed and bear remnants of somewhat curved guttered spines. Aperture small and oviform, white, interior lavender with dark brown bands. Labial varix broad and flaring, labial lip ornamented with 7 to 8 raised and scalloped denticles, columella smooth, anal notch absent. Siphonal canal broad, short, completely closed and only slightly recurved for a short distance. Operculum with a basal nucleus; the animal is yellowish-brown in colour.

**Size:** 20 mm to 36 mm.

**Type locality:** None.

**Habitat:** Under coral rocks on clean sand and coral rubble substratum, from 0 to 5 fathoms. Rare.

**Distribution:** Mamanuca group. West off Viti Levu. – ?

**Discussion:** This species differs from *Favartia brevicula* in features of form, sculpture, aperture and anterior canal; the latter is broad and short and lacks the tube-like, turned over extension of the canal of *F. brevicula*.

#### *Phyllocoma* TAPPARONE-CANEFRI 1881

*Phyllocoma* TAPPARONE-CANEFRI, 1881, Ann. Soc. Malac. Belg. Mém., 15: 44 – Type species by SD (WENZ, 1941) *Triton convolutus* BRODERIP, 1833

**Characters:** Shell small, ranellid in appearance, spire higher than aperture, whorls subulate and convex, early whorls fenestrate. Sculptured with strong spiral cords, axial ridges and 2 plain but prominent varices at every whorl. Labial lip calloused, glazed and smooth, anal notch shallow; siphonal canal short, open and recurved.

**Discussion:** The genus is assigned to the Muricinae only tentatively. THIELE (1929) describes and figures the radula of *Phyllocoma* as having a rhachidian with almost equal-sized 3 main cusps; the operculum is said to have a basal nucleus. A tricuspid rhachidian of the radula may be found in Muricinae, Typhinae and Rapaninae, and an operculum with a basal nucleus is present in the first 2 subfamilies; in shell morphology the genus appears to stand alone. Shell morphology, however, is in certain cases of little assistance in a supraspecific division of a group. In the past, toxoglossate turrids were classed with stenoglossate mitrids on account of the similarity in shell morphology. It would be reasonable to assume that a particular radula type is peculiar to a group of species due to their evolutionary process through time from a common ancestral stock, and not only because of divergence in food requirement. It is possible, however, that the radula type of *Phyllocoma* described by THIELE (*op. cit.*) may

really belong to *Galfridus* IREDALE, 1924 and may after all be appreciably different from *Phyllocoma* s. str. Until more information is known about the anatomy of the type species, the subfamilial position of *Phyllocoma* is *incertae sedis*.

#### *Phyllocoma convolutum* (BRODERIP, 1833)

(Plate 14, Figure 4)

1833. *Triton convolutus* BRODERIP, Proc. Zool. Soc. London for 1832, pt. 1: 7

**Shell:** Shell small and solid, ivory-white or fawn in colour, spire high, whorls subulate and convex. Teleoconch consists of about 8 whorls apart from protoconch which was missing in specimens examined. Sculptured with prominent raised spiral ridges which number from 18 to 20 on the body whorl and 8 to 10 on the penultimate whorl; spiral ridges closely axially striate, terminating as close-set spiral grooves at the base. The first 5 whorls are fenestrate in appearance, with axial and spiral ridges intersecting. Aperture large and oval, ivory-white in colour, labial lip slightly elevated and ornamented with 20 to 23 denticles which extend towards the interior of the aperture; columella heavily calloused, smooth and porcellaneous, anal notch moderately distinct, interior of aperture light brown. Siphonal canal short and open, moderately recurved towards the dorsum.

**Size:** 20 mm to 26 mm.

**Type locality:** None.

**Habitat:** On sand and coral rubble substratum in 15 fathoms. Rare.

**Distribution:** South Viti Levu and Mamanuca group, West off Viti Levu. – From the Philippine Islands to Japan, North Australia and the Fiji Islands.

#### Tritonaliinae

##### *Homalocantha* MÖRCH, 1852

*Homalocantha* MÖRCH, 1852, Cat. Conch. Yoldi, 1: 95 – Type species by M *Murex scorpio* LINNAEUS, 1758

**Characters:** Shell moderately small, solid, spire low, whorls angulate and convex. Teleoconch consisting of 4 to 5 whorls, protoconch of 1 to  $1\frac{1}{2}$  nuclear whorls. Sculptured with strong and distant spiral cords, fine intermediate spiral striae, 5 to 6 varices on body whorl and 5 to 7 varices on penultimate whorl. Varical fronds moderately long, T-shaped and open at distal end, numbering *ca.* 2 to 6 on the labial varix and 1 to 3 on the siphonal canal. The webbing between labial digitations is prominent in the type species but can be absent in other members of the genus. Aperture small, roundly ovate, labial lip with

scalloped denticles, columella smooth, anal notch absent. Siphonal canal moderately broad and long, closed part of the way, but open and recurved at end.

*Homalocantha anatomica* (PERRY, 1811)  
(Plate 15, Figure 16; Text figure 9)

1811. *Hexaplex anatomica* PERRY, Conchology, pl. 8, fig. 2

1823. *Murex rota* MAWE, Linn. Syst. Conch., p. 131, pl. 26, fig. 3

1921. *Murex pele* PILSBRY, Proc. Acad. Nat. Sci. Philadelphia for 1920: 318, pl. 12, figs. 29, 30

**Shell:** Shell moderately light in weight, solid, generally dirty-white in colour throughout. Whorls angulate, numbering 4 apart from protoconch which is calcified in adult specimens. Sculptured with 2 prominent cords on the body whorl and fine small cords at the labial varix; varices number from 5 to 6 per whorl, varical digitations prominent, compressed and open. Aperture small, raised, white in colour, labial varix with 2 primary digitations; labial lip with irregular scalloped denticles, columella smooth,



Figure 9

Operculum of *Homalocantha anatomica* (PERRY)

anal notch absent. Siphonal canal moderately long, closed for part of the way but open for about  $\frac{1}{3}$  of its total length towards the distal end.

**Size:** 34 mm to 56 mm.

**Type locality:** East Indies.

**Habitat:** Under coral rocks, on sand and coral substratum, in 0 to 2 fathoms. Moderately rare.

**Distribution:** Throughout the Fiji Islands. — From the Red Sea to Japan, Fiji and the Hawaiian Islands.

**Discussion:** D'ATTILIO (1964, 1964a) specifically differentiated *Homalocantha anatomica* and *H. pele* on the basis of main cord characters. He described and figured the Indian Ocean *H. anatomica* (from the Red Sea, Mozambique and Zanzibar), showing 3 main primary cords emanating from the body whorl and terminating in frondose digitations. The Hawaiian and Japanese *H. pele* were shown to possess only 2 main cords. All Fiji specimens collected to date are sculptured with only 2 main cords on the body whorl, while all other cords are secondary and degenerate. No comparison could be made with

Indian Ocean *H. anatomica*; however, should these differences in main cord characters really be stable, then a subspecific separation of the Indian Ocean *H. anatomica* (Red Sea to Philippine Islands) and the Pacific *H. anatomica pele* (Japan to New Guinea, Fiji and the Hawaiian Islands) would be warranted. For further discussion on the species see REHDER (1964).

*Vitularia* SWAINSON, 1840

*Vitularia* SWAINSON, 1840, Treat. Malac., p. 297 — Type species by M *Vitularia tuberculata* SWAINSON, 1840 = *Murex miliaris* GMELIN, 1791

**Characters:** Shell solid, moderate in size, whorls depressed, body whorl keeled; whorls number 4 to 5 apart from protoconch of 1 to 1½ nuclear whorls. Sculptured with 7 to 9 oblique and nodulose varices, spiral ridges and occasionally scabrous granules. Aperture elongate-ovate, labial lip denticulate, columella sinuous, depressed and smooth, anal notch obsolete. Siphonal canal short and open, slightly recurved. Operculum with a dextro-lateral nucleus. **Discussion:** SWAINSON (1840) applied the spelling *Vitulina* on page 64 and *Vitularia* on page 297. GRAY (1847, p. 134) adopted *Vitularia* as the correct spelling from SWAINSON's multiple original spellings.

IREDALE (1929) established the genus *Transtrafer* for the new species *T. longmani* IREDALE, 1929, and in way of explanation mentioned the "striking resemblance" of his new species to the "American *Murex vitulinus* LAMARCK." This is obviously a case of mistaken identity, as *M. vitulinus* LAMARCK (= *M. miliaris* GMELIN) is an Indo-Pacific species, and conspecific with *T. longmani* IREDALE. Several writers have passed comments on the casual way in which IREDALE erected his new molluscan genera, and a detailed discussion on their nomenclatural validity can be found in SOLEM (1964). *Transtrafer* is just another of IREDALE's undefined generic groups, which would have qualified as a *nomen nudum* had it been described only 6 months later. Australian workers would certainly render malacological science a great service by re-describing IREDALE's several hundred generic groups and thousand odd species.

*Vitularia miliaris* (GMELIN, 1791)

(Plate 15, Figure 18; Text figure 10)

1791. *Murex miliaris* GMELIN, Syst. Nat., ed. 13, p. 3536, no. 39 (ref. MARTINI, 1777, 3: 303, vign. 36, figs. 1-5 & CHEMNITZ, 1788, 10, t. 161, figs. 1532-1535)

1798. *Purpura onagrina* RÖDING, Mus. Bolten., p. 139, no. 1751 to 1753 (ref. *sup. cit.*)

1816. *Murex vitulinus* LAMARCK, Tabl. Encycl. Méth., p. 5, pl. 419, figs. 1 a, 1 b, 7 a, 7 b

1840. *Vitularia tuberculata* SWAINSON, Treat. Malac., p. 297  
 1843. *Murex purpura* DESHAYES & MILNE-EDWARDS, Hist. nat. anim. sans vert., 2ème edit., 9: 595 (nom. nov. pro *M. vitulinus* LAMARCK, 1816)  
 1861. *Vitularia sandwicensis* PEASE, Proc. Zool. Soc. London for 1860: 397 (spec. juv.)  
 1929. *Transtrafer longmani* IREDALE, Mem. Queensld. Mus., 9 (3): 290, pl. 31, fig. 10 (shell), fig. 11 (protoconch)

**Shell:** Shell moderately heavy and solid, dirty-grey to orange-brown in colour, occasionally ornamented with 1 to 3 rows of dark brown spots on varices on the body whorl. Teleoconch consisting of 4 to 5 whorls, protoconch of  $1\frac{1}{2}$  nuclear whorls. Early whorls flattened, body whorl with a peripheral keel and 7 to 8 oblique varices; sculptured with tightly packed spiral ridges or scabrous small granules. Aperture elongate, edge of aperture variable in colour, either bluish-white, creamy-yellow or reddish-orange, occasionally with 1 to 3 dark brown bars on labial lip; deep interior of aperture generally white. Labial lip angulate, ornamented with 7 to 13 denticles, columella



Figure 10

Operculum of *Vitularia miliaris* (GMELIN)

calloused, sinuous and smooth, anal notch obsolete. Siphonal canal short and open and only slightly recurved. Operculum (Text figure 10) with a dextro-lateral nucleus. Size: 15 mm to 63 mm.

**Type locality:** None.

**Habitat:** Under coral rocks on muddy sand substratum, in shallow water; juvenile specimens in sand and weed pockets of coral reefs. Moderately common.

**Distribution:** Throughout the Fiji Islands. — From the Seychelles Islands to Japan, East Australia and the Hawaiian Islands.

**Discussion:** *Vitularia miliaris* is a variable species, especially in colour and sculpture. LAMARCK's *Murex vitulinus* is conspecific with *M. miliaris* GMELIN. In LAMARCK's 1822 work, *M. vitellinus* bears the same synonymy as *M. miliaris* GMELIN and *Purpura onagrina* RÖDING.

## UNCONFIRMED REPORTS

### *Homalocantha martinetana* (RÖDING, 1798)

1798. *Purpura martinetana* RÖDING, Mus. Bolten., p. 141, no. 1778 (ref. CHEMNITZ, 1788, 10, t. 161, figs. 1536, 1537)  
 1817. *Murex fenestratus* DILLWYN, Descr. cat. rec. shells, 2: 716 (ref. CHEMNITZ, *op. cit.*, figs. 1536, 1537 & FAVANNE, 1780, t. 35, fig. C1)  
 1963. *Murex (Homalocantha) fenestratus* DILLWYN, SHIKAMA, Sel. shells world, 1: 72, pl. 56, fig. 5)

This species is known from only one very worn specimen found in shell debris at Caboni Beach, North Viti Levu. The digitations on the labial varix are completely worn away, but the deep pits between the axial ribs are still visible.

The species has been reported from the Red Sea, Japan and Okinawa.

## FOSSIL RECORD

### *Murex cf. M. recurvirostris* BRODERIP, 1833

1934. *Murex (Murex) aff. recurvirostris* BRODERIP, LADD, Bull. Bern. P. Bishop Mus., 119: 224-226, pl. 40, figs. 3-5

LADD (1934) reported the fossil species from stations 59 and 165 (banks of Wailoa river near Nasogo, Viti Levu, elevation 995 feet) from deposits which are probably Lower Miocene (*vide* LADD, 1966). This species does bear a resemblance to the Recent species *M. recurvirostris* BRODERIP from the West Indies, and especially to the subspecies *M. recurvirostris rubidus* F. C. BAKER, 1897. It differs only in the slightly more numerous axial ribs and denticulate columella. There is no similar species living in Fiji today.

## SUMMARY

The majority of the Fijian molluscs live within the littoral zone, while only a few species are confined to deeper water. Of the enumerated muricid species, 70% live in the intertidal region and only 30% inhabit the sub-littoral zone.

The total number of species recorded in the various muricid genera is as follows:

<i>Murex</i>	2
( <i>Haustellum</i> )	1
<i>Chicoreus</i>	8
<i>Pterynotus</i>	1
( <i>Naquetia</i> )	2
<i>Poirieria</i>	1
<i>Phyllocoma</i>	1
<i>Favartia</i>	2
<i>Homalocantha</i>	1
<i>Vitularia</i>	1
Total	20 species

### Addendum

Just before going to press we received the following paragraphs from the author. We are pleased to be able to include them here.

Prior to the manuscript's going to press a specimen of *Homalocantha anatomica* (PERRY, 1811) was collected by the author; the radula was extracted and examined. The specimen had 3 main primary cords emanating from the body whorl and terminating in T-shaped digits; as both three-corded and two-corded specimens are found in the Fiji Islands, the Pacific *H. pele* (PILSBRY, 1921) cannot be separated from the nominal species *H. anatomica*.

**Radula:** Rhachidians with 3 broad main cusps, intermediate denticles lacking; central cusp longer than side cusps. Length of radular ribbon 6.1 mm, width 0.16 mm in an animal with a shell 43.0 mm long. The ribbon is trans-

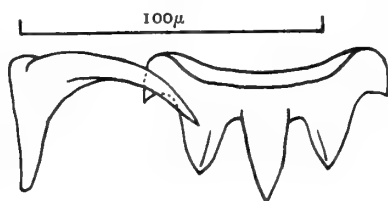


Figure 11

Half Row of Radular Teeth of *Homalocantha anatomica* (PERRY)  
Fiji Islands

lucent white and is comprised of 295 rows (+17 nascent) of teeth; the teeth in the anterior rows are greatly worn. The penis is light fawn in colour, 3.1 mm in length and very similar to the penis of *Chicoreus brunneus* (LINK, 1807) and *C. carneolus* (RÖDING, 1798).

**Animal:** Sole of foot light creamy-brown in colour, dorsum of foot white. Tentacles slender, moderately short, broad at base, white in colour; siphon whitish, eyes very small, black in colour.

The radula of *Homalocantha anatomica* is muricid, and the genus therefore should be removed from Tritonaliinae and placed in the subfamily Muricinae. *Homalocantha* should be placed near *Pterynotus* SWAINSON, 1833 and *Naquetia* JOUSSEAUME, 1880, as these genera encompass species with tricuspid rhachidians without the intermediate denticles.

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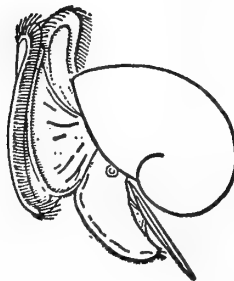
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# A Review of the Living Tectibranch Snails of the Genus *Volvulella*, with Descriptions of a New Subgenus and Species from Texas

BY

HAROLD W. HARRY

A&amp;M Marine Laboratory, Galveston, Texas 77550 and Rice University, Houston, Texas 77001

(21 Text figures)

THIS STUDY BEGAN with an attempt to identify some specimens of *Volvulella* from Galveston, Texas, which proved to belong to an undescribed species more similar to one from the west coast of North America than to any hitherto known from the Atlantic. It is proposed as the type of a new subgenus. Snails of this genus live subtidally and to several hundred meters depth in tropical and warm temperate oceans throughout the world. They are local in occurrence and rarely abundant. It is not surprising therefore that the limits of species variation are poorly understood. There has also been confusion of the generic nomenclature, and the family to which they belong is still a moot question. The most recent monograph of the genus is by PILSBRY (1893). Monographic treatment of the whole genus has not here been attempted, since sufficient material was not available. Effort was concentrated on differentiating the species on American shores. A synonymy is given of the species of the eastern Atlantic, probably representing only one biological species, and a list of the nominal species of the western Pacific and Indian Oceans is appended, with comments. Five species named by DALL (1919) from the west coast and one from the east coast (DALL, 1927) were never illustrated. Opportunity to study this problem at the U. S. National Museum allowed me to make camera lucida drawings of the type specimens of DALL's nominal species. Measurements were made with an ocular micrometer, and are possibly more exact than those given by DALL. Most of DALL's type material was series of badly worn specimens, from which he evidently made composite descriptions. Lectotypes are here designated for each lot.

I am obliged to the Bureau of Commercial Fisheries of the U. S. Fish and Wildlife Service, Galveston, and especially to Messrs. Robert Temple, Clarence Fisher and Charles Guice for the material from the western Gulf of

Mexico. The many courtesies of Dr. Harald Rehder, Dr. J. P. E. Morrison and Dr. Joseph Rosewater, while I worked at the U. S. National Museum, are gratefully acknowledged. This study was supported in part by National Science Foundation Grant GB 2753.

This genus has sometimes been placed in a separate family (Volvulidae, LOCARD, 1892; Rhizoridae DELL, 1956). After an extensive study of the anatomy of *Volvulella persimilis* from Brazil, MARCUS & MARCUS (1960) concluded that tentatively this genus should be placed in the Retusidae.

## *Volvulella* NEWTON, 1891

*Volvula* A. ADAMS in SOWERBY's Thesaurus Conchyliorum 2: 555. Type by SD of A. ADAMS, 1862, Ann. and Mag. Nat. Hist. Ser. 3, vol. 9, p. 154, *V. acuminata* (BRUGUIÈRE) (= *Bulla acuminata* BRUGUIÈRE, 1792). Not *Volvula* GISTEL, 1848, Naturgesch. Thierr. f. Höhere Schulen, p. viii (Diptera).

*Volvulella* NEWTON, 1891, British Oligocene and Eocene Mollusca, p. 268. Substitute name for *Volvula* A. ADAMS, 1850, hence with same type species.

*Rhizorus* MONTFORT, 1810 of authors, not of MONTFORT.

ARTHUR ADAMS (1850) did not designate a type from among the 5 species which he included in *Volvula*, proposed as a subgenus of *Bulla*, nor was there otherwise intrinsic fixation of the type. MENKE (1854) declared *Volvula* ADAMS to be a synonym of *Rhizorus* MONTFORT, citing as type *V. acuminata*, which species he admitted he did not have. Since the two generic concepts are not the same, his designation of type can not be valid for *Volvula* ADAMS. H. & A. ADAMS (1854) also denied the identity of these two concepts. Their choice of the Australian species, *V. rostrata* ADAMS (1850) as an "example" of the genus was not construed by them or any subsequent

author to be *per se* a designation of the type species, but it may have led BUCQUOY, DAUTZENBERG & DOLFUS (1886) to designate that species as type. In 1862 A. ADAMS designated the first species of his monograph of 1850 as type, the European *V. acuminata* BRUGUIÈRE. PILSBRY designated the same type in 1893, but neglected to indicate the basis for his type selection. All subsequent authors have erroneously adopted the type designation of BUCQUOY *et al.*

NEWTON (1891) renamed ADAMS' concept, thinking *Volvula* was a homonym of *Volvulus* OKEN, 1815. By modern concepts of nomenclature these are not homonyms, since they differ by gender as shown by the endings. Therefore PILSBRY (1893) rejected NEWTON's substitute name, but he overlooked the genus *Volvula* GISTEL, 1848, which does invalidate *Volvula* ADAMS, 1850.

Several authors have continued to use *Volvula* A. ADAMS for this group of snails (NICKLÈS, 1950; PRUVOT-FOL, 1954), although GRANT & GALE (1931) gave the valid argument for accepting *Volvulella*.

The genus *Rhizorus* MONTFORT, 1810 (Conch. Syst. 2: 339, and plate on opposite page) has been considered by several authors during the nineteenth century as applying to this group of snails, but most rejected it as representing some other genus or as a result of their subjective nomenclatural conservatism (H. & A. ADAMS, 1854; JEFFREYS, 1867; PILSBRY, 1893; DALL, 1889). The single species which MONTFORT included in his genus, and designated as type, *Rhizorus adelaidis*, was described as being as big as a grain of millet. It came from the island of Elba, Italy, but was thought probably also present in England. He refers to a figure in SOLDANI, a work not available to me, nor evidently to most writers who have studied

the question. To show that MONTFORT's genus can scarcely apply to *Volvulella*, a tracing of his illustration of *R. adelaidis* is here reproduced (Figure 1). It has the apex broadly truncate, scarcely tapering, and widely umbilicate; the aperture extends well above the apex, and is not curved toward the columellar axis there. All of these characters contrast with *Volvulella*, which, though some variants may be spineless and minutely umbilicate, have the aperture curved distinctly if only slightly toward the shell axis. Moreover, there are much better candidates for MONTFORT's concept, from the area he indicated, than the single species of *Volvulella* which is generally recognized from there. His concept may apply to something like "*Cylichna conulus* DESHAYES" as described and figured by FORBES & HANLEY (1851, 3: 517; 4: pl. 114 c, figure 7). GRAY (1847) early associated MONTFORT's genus with such forms.

Several major works of recent years have adopted *Rhizorus* MONTFORT for this genus (e.g. WINCKWORTH, 1932; ABBOTT, 1954; POWELL, 1962). KEEN (1947) and PALMER (1958) have protested its use in this respect.

Snails of the typical subgenus have small shells (up to 9 mm long) which are tapering, ovate or subcylindrical. They are completely without intrinsic color, being light grey and translucent when taken alive, but soon turning snow white and opaque after "weathering" in nature. The aperture is narrow, elongate, rounded basally and extended the entire height of the shell. There is no columellar lamella or other apertural dentition. At its apical end the aperture bends over the apex of the shell, and the parietal wall here forms a spine which completely covers the apex, so that only the final whorl is visible. This, together with the non-determinate growth of the shell, makes it difficult to recognize juvenile shells as such, unless one has a large series available. The apical end of the aperture is almost or entirely as far advanced in the direction of growth as the rest of the outer lip. It is not deeply sinuate, and consequently extends as high as the tip of the spine in apertural view. There is a thin, colorless periostracum which is soon destroyed after death. Spiral sculpture of fine, incised lines, rather widely spaced, occurs at both ends of the shell (macro-spirals) in most species, and most (all?) have finer, closely set, wavy lines incised over the middle part of the whorl (micro-spirals). The micro-spirals are almost limited to the periostracum, and rarely evident on the even slightly weathered specimens. The shells are always imperforate basally, but a slight elevation of the narrow columellar lip from the whorl defines a furrow and minute pseudo-umbilicus.

Most characters show considerable variation within a species. The apical extent of the aperture and its bending

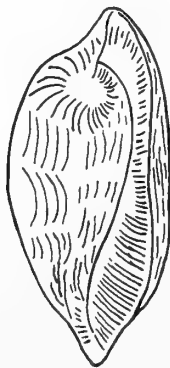


Figure 1

Tracing of figure of "*Rhizorus adelaidis*" from volume 1, page 338, MONTFORT, 1810

toward the columellar axis may vary even within specimens from one locality. This results in the spine varying from long and tapering to short and blunt, or in extreme cases, being replaced by a minute umbilicus at the apex. In worn shells the spine seems to undergo similar degradation, even if it were long and acute in the living animal. The spiral lines are variable in unworn shells of a species from one locality, and weathering rapidly degrades them. The basal lines are stronger and more persistent than the apical ones, and both are generally more so than the micro-spirals. The form may vary from oval to more elongate, perhaps within the growth of a single individual. But the shape of the shell seems to vary less than other characters within a species, and therefore is the most useful criterion at the species level.

Few species have special features which aid in identification, but examples are: the unusual thickness of the shell in *Volvulella paupercula* and *V. catharia*; the transverse riblets near the apex of *V. recta*; the tendency of the shells of *V. panamica* and *V. texasiana* to be stained with iron, and the peculiar apical sinus in the lip of these species; the apical ridge in *V. texasiana*.

At least 4 distinct groups of species are living today. The eastern Atlantic may have only one of the 4, but the western Atlantic, eastern Pacific and Indo-Pacific areas all contain very similar representatives of the other 3 species groups. Just how closely related these analogous populations are from the standpoint of taxonomy can not be definitely decided at present. The analogous species of each region differ so little, and then chiefly in their form, that a comparison of specimens from the several areas is the only convincing demonstration of their distinctness. Although only one species is generally recognized from the eastern Atlantic (BUCQUOY *et al.*, 1882; NICKLÈS, 1950; PRUVOT-FOL, 1954), other species have occasionally been recognized from there (DALL, 1889; PILSBRY, 1893). The following table summarizes the analogous species of the Atlantic and eastern Pacific Oceans. As my study of the populations of the Indian and western Pacific Oceans is based almost entirely on the literature, I have not included them in this table, but appended a list of the nominal species below.

Eastern Atlantic	Western Atlantic	Eastern Pacific
Subgenus <i>Volvulella</i> s. s.		
<i>V. acuminata</i>	<i>V. persimilis</i>	<i>V. cylindrica</i>
none?	<i>V. recta</i>	<i>V. californica</i>
none?	<i>V. paupercula</i>	<i>V. catharia</i>
Subgenus <i>Paravolvulella</i> , new subgenus		
none?	<i>V. texasiana</i>	<i>V. panamica</i>

## Species of the Eastern Atlantic

### *Volvulella acuminata* (BRUGUIÈRE, 1792)

- Bulla acuminata* BRUGUIÈRE, 1792, Encycl. Méth. vol. 1, prt. 2, p. 376, no. 9. Not figured. Type locality: not specified; evidently the Mediterranean, near northwestern Italy
- Volvula cylindrica* E. A. SMITH, 1872, Proc. Zool. Soc. London p. 738, plt. 75, fig. 29. Not *V. cylindrica* CARPENTER, 1864
- Volvula smithii* PILSBRY, 1893, TRYON's Man. Conch. 15: 233-234, plt. 26, fig. 65. New name for *V. cylindrica* SMITH, 1871
- Volvula acuminata* var. *brevis* PILSBRY, 1893, TRYON's Man. Conch. 15: 235, plt. 60, fig. 11. Type locality: Northern Europe, Mediterranean
- Volvula suavis* THIELE, 1925, Wiss. Ergeb. d. deutsch. Tiefsee Exp. 17 (2): 238, plt. 31, fig. 20. Type locality: 16° 26.5' S. Lat., 11° 41.5' E. Long. (off Angola, Africa). He compared the single shell found with *V. acuminata*

There is variation in shape of this species, at least among the several lots from northern Europe of the Jeffreys collection in the U. S. National Museum. Larger specimens tend to be more elongate and more slender than smaller ones, which are more oval. The spine is elongate and acutely tapering. Completely spineless specimens were not found among the fresh, non-worn shells. Macrospiral lines occur at both ends, and faint micro-spirals are evident in many fresh shells. The eastern Atlantic shells always seem slightly more inflated than *Volvulella persimilis*, although the difference is very small, and requires actual comparison of specimens to demonstrate it adequately.

The range of *Volvulella acuminata* extends from Norway along the coast of Europe, including the Mediterranean, and south along the African coast to Angola (NICKLÈS, 1950). PRUVOT-FOL (1954) lists it also from the Gulf of Suez at the head of the Red Sea, and indicates *V. oxytata* (BUSH) and *V. persimilis* (MÖRCH) may be only varieties. She thought this species might be circumterrestrial, as did MELVILL (1906).

Figure 2 (height 3.94 mm, diameter 1.69 mm) was drawn from one of 4 specimens on a card (USNM 175142) noting one of these shells was drawn as figure 1 of plate 93 of JEFFREYS' "British Conchology." The exact locality of the specimens was not indicated, but it is presumably the British Isles. Figure 3 (height 4.06 mm, diam. 1.25 mm, USNM 175146) is one of a large lot from St. Magnus Bay, Shetland Islands. It illustrates a more cylindrical variant, with less acute spine. The specimen had been bored 3 times by some predaceous snail.

## Species of the Western Atlantic

*Volvulella persimilis* (MÖRCH, 1875)

*Volvula persimilis* MÖRCH, 1875, Malak. Blätter 22: 179. Not figured.

Type locality: "M. Antil." (Antilles). 1900, DAUTZENBERG, Mém. Soc. Zool. France 13: 155 - 156; pl. 9, fig. 10

*Volvula oxytata* BUSH, 1885, Trans. Conn. Acad. Sci. 6 (2): 468; pl. 45, fig. 12. Type locality: off Cape Hatteras, N. Car. in 7 to 17 fathoms

*Volvulella mörchi* DALL, 1927, Proc. U. S. Nat. Mus. 70: 22. Not figured. Type locality: off Georgia, U. S. Fish. Comm. Sta. 2415, 440 fathoms

*Volvula ischnatracta* PILSBRY, 1930, Proc. Acad. Nat. Sci. Philadelphia 82: 301; text fig. 1, p. 302. Type locality: Andros Bank, west of Middle Bight, about 12 miles within the western edge of the bank, in 3½ fathoms (Bahamas)

This species is the western Atlantic counterpart of *Volvulella acuminata*, from which it is differentiated only by subtle differences of curvature of the whorl. The difference seems to be consistent when shells from the two sides of the ocean are compared side by side. The sculpture on both species is the same; prominent, broadly spaced spiral lines at both ends of the shell, and finer spiral lines between. To recognize *V. persimilis* as merely a subspecies of *V. acuminata* might be equally acceptable. *Volvulella persimilis* may not extend north of North Carolina, and thus the ranges of the two species do not, as presently known, meet in the North Atlantic. Numerous lots of *V. persimilis* are present in the U. S. National Museum from off Beaufort, North Carolina, and also from along the Florida Keys (J. B. Henderson) as well as smaller lots from Puerto Rico and Cuba. They range in depth from 15 to 209 fathoms. MARCUS & MARCUS (1960) described the anatomy of specimens from Brazil. Shells from Beaufort are long spined forms. Figure 4 (USNM 35871, height 3.50 mm, diam. 1.25 mm) is drawn from a specimen collected by the U. S. Fish Commission, Station 2112, in 15 fathoms off Cape Hatteras, North Carolina. It was sent to Dall by Bush. Whereas it may not be a paratype, it is at least an authentically identified specimen of what BUSH named *Volvula oxytata*, from the type locality. The terminal spiral lines are present on this specimen, but finer spiral lines on the middle of the shell were not seen, possibly due to slight weathering.

In the more southern part of the range of this species, there are specimens with shorter, blunted spines, and even no spine but a small apical umbilicus. Such forms occur in the same lots with acutely spined shells, but tend to be more abundant than the latter. It is probably intrinsic variation, rather than a common characteristic regularly evoked by a special environment. It was on such specimens that the species names *Volvulella moerchi* DALL and *Volvula ischnatracta* PILSBRY were based.

MÖRCH's original description of *Volvula persimilis* was based on a single specimen received from Krebs from the Antilles. His name is applied to the present species in part through a process of elimination, because his description best fits this species of those known to occur in the western Atlantic, and because he adequately differentiated it from the only other common shallow water species of the area (*V. recta* MÖRCH). The case for recognizing MÖRCH's name is much better than that for recognizing *V. acuminata* (BRUGUIÈRE). The original description [bracketed words inserted] of *V. persimilis* (MÖRCH) and my translation follow:

"Differt a *Volvula angustata* A. AD. (Thes. XV 1850 p. 596 n 121, f 153) t. spiraliter subtilissime striata sub lente vix detegenda, solidiore; columella valida obliqua, plica crassa recta. Differt a praecedente [*V. recta* "d'ORB." MÖRCH = *V. acuta* d'ORB.] t. subcylindrica. Long 4½ mm; diam. 1½ mm. Hab. M. Antill. (Krebs) spm. unicum."

"Differs from *Volvula angustata* A. ADAMS (SOWERBY's Thesaurus Conchyliorum vol. 15, 1850, p. 596, No. 21, fig. 153) in that the shell is more solid, and spirally, very finely striate, the striae scarcely detectable under a lens; columella strongly oblique, with a coarse, straight lamella. It differs from the preceding [*V. recta* "d'ORB." MÖRCH = *V. acuta* d'ORB.] in that the shell is subcylindrical. Length 4½ mm, diameter 1½ mm. Habitat M. [major? minor?] Antilles, a single specimen received from Krebs."

The figure of *Volvulella angustata* (A. ADAMS) (from the Philippines) referred to fits very well the brevi-spinous forms of this species in the West Indies. The aperture extends to the tip of the spine, thus differentiating it from *V. texasiana*, and the cylindrical form differentiates it from the bulbous *V. recta* and *V. paupercula*.

DAUTZENBERG (1900) redescribed and figured *Volvulella persimilis* from shells obtained at 10 fathoms off Venezuela. Although he argues that this species is distinct from *V. oxytata* (BUSH), the described and figured shells are quite within the range of variation of the species as here understood. MARCUS & MARCUS (1960) also thought these two names are synonyms.

Figure 5 is a drawing of the single specimen on which *Volvulella moerchi* DALL, 1927 was based (USNM 108268, U. S. Fish Commission, Station 2415). The shell is very worn, with the spine completely broken off and the outer lip badly damaged. It is chalky and opaque, showing no sculpture: height 3.68 mm, diam. 1.55 mm (DALL stated: Height 3.5; diameter 1.25 mm.). This specimen may have been accidentally present in the 440 fathom station where it was taken. DALL made no mention of depth in his description, but "440 fms." is on the label. He noted it "is nearest *V. persimilis* MÖRCH but is smaller and not spirally striated."

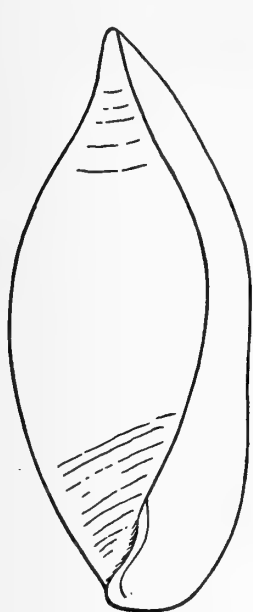


Figure 2

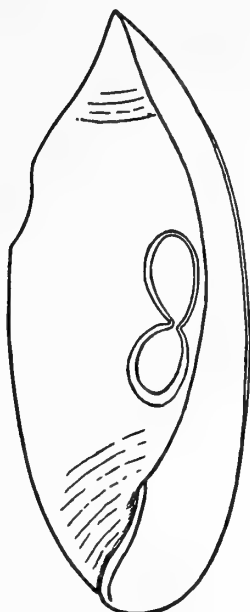


Figure 3



Figure 4



Figure 5

Figure 2: *Volvulella acuminata* (BRUGUIÈRE). 3.94 mm high

Figure 3: *Volvulella acuminata* (BRUGUIÈRE). England. 4.06 mm high

Figure 4: *Volvulella persimilis* (MÖRCH) (authentic specimen of *Volvulella oxytata* (BUSH); 3.50 mm high)

Figure 5: Holotype of *Volvulella moerchi* DALL (= *V. persimilis* (MÖRCH)) 3.68 mm high

PILSBRY (1930) may have had only a single specimen available to describe *Volvulella ischnatracta*. It is completely spineless (broken?), but has an elongate form characteristic of this species, and spiral lines at both ends.

#### *Volvulella recta* (MÖRCH, 1875)

*Bulla acuta* D'ORBIGNY, 1842. Mollusca, in SAGRA, Hist. . . . Cuba 1: 126; plt. 4, figs. 17 - 20. Type locality not specified; cited from Cuba, Jamaica, Guadeloupe and Martinique and "toutes les Antilles." Non *Bulla acuta* GRATELOUP, 1828, Bull. Hist. Nat. Soc. Linn. Bordeaux 2 (9): 87

*Volvula recta* "D'ORBIGNY" MÖRCH, 1875. Malak. Blätter 22: 179. Not figured. This fortuitous *lapsus calami* merely cites the page and illustration in D'ORBIGNY, 1842 of *Bulla acuta* D'ORBIGNY, but meets all requirements for rectifying D'ORBIGNY's homonym

*Volvula minuta* BUSH, 1885. Trans. Conn. Acad. Sci. 6: 469; plt. 45, fig. 11. Type locality: off Cape Hatteras, N. Car., in 14 to 16 fathoms

*Volvula bushii* DALL, 1889. Bull. Mus. Comp. Zool. 18: 51. Not figured. Type locality: Station 2602, 36 miles S.  $\frac{1}{2}$  W. from Cape Hatteras, N. C., in 124 fathoms, sand. 1925, DALL, Proc. U. S. Nat. Mus. 66: 31; plt. 25, fig. 3

This, the first species in the genus to be described from the New World, had one of the most succinct descriptions and better illustrations of any from that area. The following is a free translation of D'ORBIGNY's description in French.

"The shell is oblong, bright, thin, swollen in the middle, thinning at the extremities, marked in front by several spiral striations and behind by several others, a little in front of the extremity, which is transversely striate. Spire entirely enclosed, without umbilicus, replaced by a long, sharp prolongation. Aperture very straight, a little sinuate, prolonged behind, enlarged in front; columella a little projecting, separated by a groove from the umbilicus and forming a slight ridge. Color, uniformly white. Length 2 mm. Diam.  $\frac{3}{4}$  mm."

He specifically called attention in both the Latin and French descriptions and in the discussion to the delicate, transverse, apical striae which are unique to this species. But he referred to them as longitudinal, using the term transverse for what is here termed spiral. The transverse striae are around the apical third of the shell and extend onto the base of the spine. They are very closely spaced,

regular, and somewhat stronger than growth lines. The greatest diameter of this species is above the midpoint of the length of the shell, in contrast to all others of the East Coast. The spine may be short and blunt, but the shell is never as solid in structure as that of *Volvulella paupercula*.

The U. S. National Museum has specimens from Cape Hatteras, North Carolina, and numerous ones from the Florida Keys. It extends into the Gulf of Mexico at least

to Mobile, Alabama. These lots range in depth from 12 to 124 fathoms.

Figure 11 (USNM 44773, U. S. Fish Commission Station 2113, 15 fathoms, off Cape Hatteras, North Carolina) is drawn from a single shell of *Volvula minuta* BUSH which she sent to DALL. It is scarcely worn, and agrees closely with *Volvulella recta*, both in the shape and in having transverse striae at the apex. Spiral striae are

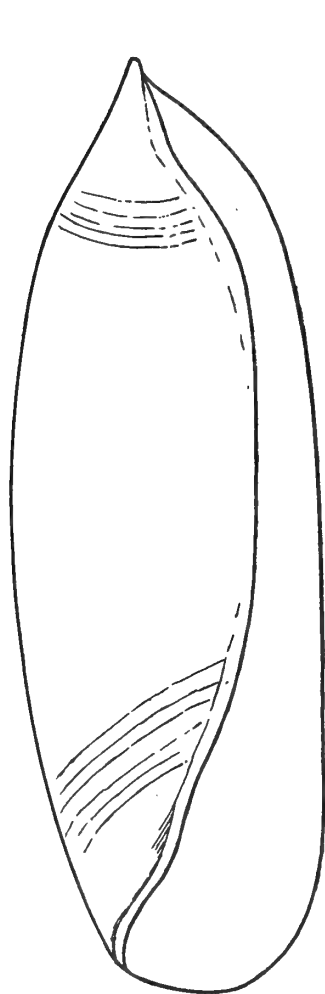


Figure 6

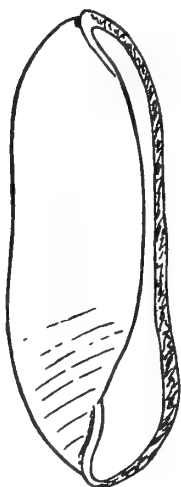


Figure 7



Figure 8

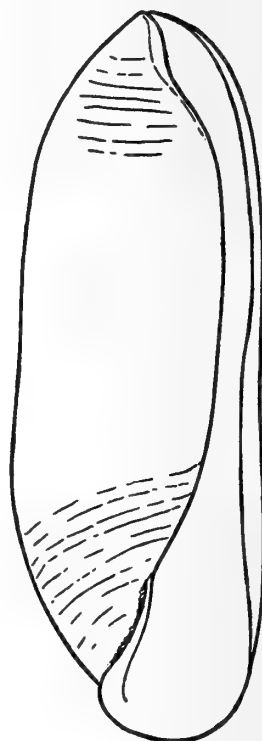


Figure 9

Figure 6: *Volvulella cylindrica* (CARPENTER). 6.19 mm high

Figure 7: Lectotype of *Volvulella cooperi* DALL

(= *V. cylindrica* (CARPENTER)). 6.45 mm high

Figure 8: Lectotype of *Volvulella callicera* DALL

(= *V. cylindrica* (CARPENTER)). 3.06 mm high

Figure 9: *Volvulella cylindrica* (CARPENTER). 7.88 mm high



Figure 10

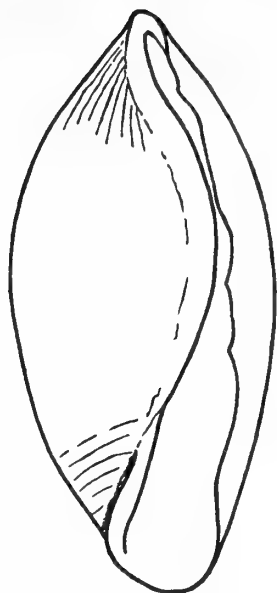


Figure 11

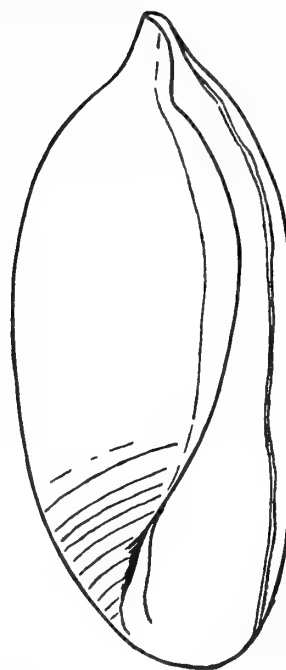


Figure 12

Figure 10: Lectotype of *Volvula bushii* DALL (= *Volvulella recta* (MÖRCH)).  
4.31 mm high

Figure 11: *Volvulella minuta* (BUSH) (= *V. recta* (MÖRCH)). 2.02 mm high

Figure 12: Lectotype of *Volvulella californica* DALL. 4.44 mm high

strong at the apical end, less pronounced basally, and none could be detected on the midregion of the shell. It may be juvenile. Height 2.02 mm, diameter 0.92 mm.

Figure 10 (USNM 95301, off Cape Hatteras, North Carolina) is drawn from the larger of two specimens which are presumably cotypes of *Volvula bushii* DALL, 1889. It agrees most closely with the dimensions cited in the original description (DALL, 1889) "Lon. 4.6; Lat. 2.3 mm," and is here designated **lectotype**. He originally cited 6 specimens; there are no locality data with this lot, but the catalogue number is that which he cited in figuring the species (DALL, 1925).

Measurements of the two shells are:

	Height	Diameter
Lectotype:	4.31	2.06
Paratype:	3.25	1.56

Both shells are opaque, white, and slightly worn. They are quite characteristic of *Volvulella recta* in shape, having a very long, acute spine, and transverse striae at the apical end. Spiral striae are present at both ends, and microspirals are evident in the middle of the shell.

#### *Volvulella paupercula* (WATSON, 1883)

*Cylichna* (*Volvula*) *paupercula* WATSON, 1883. Journ. Linn. Soc. London 17: 325. Not figured. Type locality: Lat. 18° 38' 30" N., Long. 65° 05' 30" W., North of Culebra Island, St. Thomas, West Indies. 390 fathoms. 1886, WATSON, Challenger Report, Zoology, 15: 669-670; plt. 50, fig. 5

*Volvula aspinosa* DALL, 1889. Bull. Mus. Comp. Zool. 18: 51. Not figured. Type locality: "Off the North Carolina Coast in 18 to 168 fms., sand ... Straits of Florida, 150-200 fms." 1925, DALL, Proc. U.S. Nat. Mus. 66: 31; plt. 25, fig. 5

This species is somewhat more inflated than *Volvulella recta*. Larger specimens have the greatest diameter at the midpoint of the length, rather than above it. Transverse striae at the apical end are absent, although more widely spaced growth lines extending from apex to base are generally present. Coarse spiral striae are prominent at both ends, and fine spiral lines are often well shown in fresh shells. The spine is small, but usually absent. In the latter case the aperture does not quite reach the columella, although it bends strongly toward it at the apical end. A distinct but minute apical umbilicus is present in the

aspinous specimens. The shell is unusually thick for the genus. This may be a species which is reverting to a spineless condition. The general shape and sculpture, and presence of a distinct, short spine in some specimens, suggest it is truly a *Volvulella* rather than a *Cylichna*.

The species is well represented in the collection of the U. S. National Museum by material dredged by J. B. Henderson in 1917, on the yacht *Eolis*, along the Florida Keys and off Barbados. The range in depth is from 75 to 190 fathoms.

Figure 15 (USNM 95305, off Cape Hatteras, North Carolina) was drawn from the larger of two cotypes of *Volvula aspinosa* DALL, and is here designated the **lectotype**.

Measurements of the two shells are:

	Height	Diameter
Lectotype:	3.63	2.06
Paratype:	3.06	1.75

DALL (1925) cited USNM 95302 as the type lot, but I think that was a misprint. The type locality should be restricted to North Carolina. He gave the dimensions as "Long. 4.0; Lat. 2.0 mm." (DALL, 1889).

Figures 16 (height 3.63 mm, diameter 1.94 mm) and 17 (height 2.94 mm, diameter 1.50 mm) are drawn from specimens (USNM 500381) from 94 fathoms off Barbados, and show somewhat slimmer forms of this species.

Although *Volvulella paupercula* (WATSON) was described from shells taken at 390 fathoms, and thus much

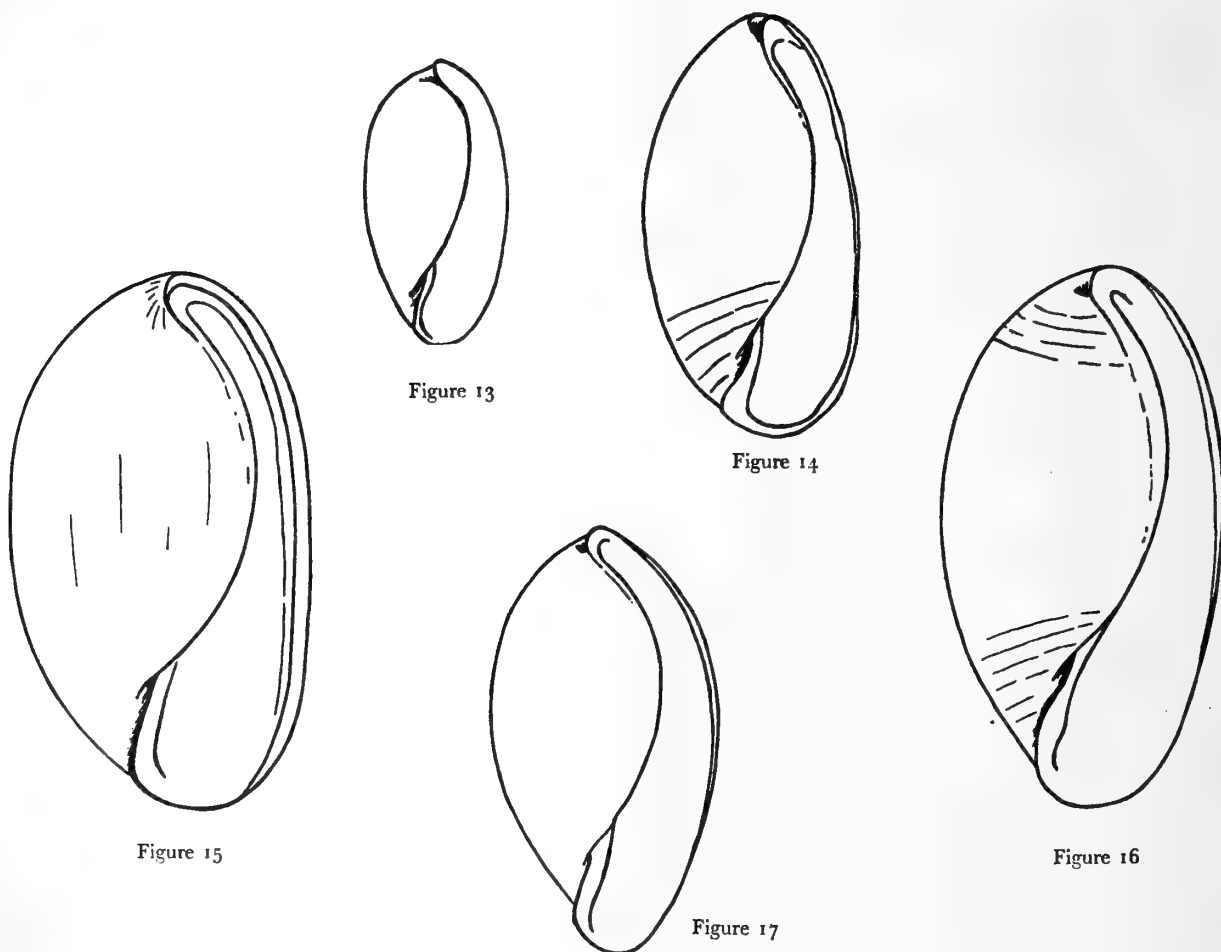


Figure 13: *Volvulella paupercula* (WATSON). Tracing of figure 5 of plate 50,

Figure 14: Lectotype of *Volvulella catharia* DALL. 2.75 mm high

Figure 15: Lectotype of *Volvula aspinosa* DALL

(= *Volvulella paupercula* (WATSON)). 3.63 mm high

Figure 16: *Volvulella paupercula* (WATSON). Barbados. 3.63 mm high

Figure 17: *Volvulella paupercula* (WATSON). Same lot as Figure 16. 2.94 mm high

deeper than any examined in the present study, the excellent description and detailed figure of it leaves little doubt that this is what DALL later named *Volvula aspinosa*. WATSON's figure has the sculpture more strongly indicated than it actually is. A tracing of his figure (without the sculpture) is here reproduced in Figure 13. The dimensions given by WATSON, converted from inches, are: height 1.55 mm, diameter 0.75 mm.

(*Paravolvulella*) HARRY, subgen. nov.

**Type:** *Volvulella* (*Paravolvulella*) *texasiana* HARRY, spec. nov.

This subgenus differs from the typical one in the more cylindrical form of the shell, with bluntly rounded rather than gently tapering shoulder; and especially in the deep, rounded sinus of the apical end of the outer lip, which appears in apertural view not to extend farther posteriorly than the base of the spine, rather than to its tip. However, the parietal lip does curve upward medial to the sinus to form the spine, which is short but acute.

There is a tendency for the species of this subgenus to be colored brown by iron stain (extrinsic coloration) in fresh specimens. This is unusual in marine mollusks. At Galveston, only a few of the off-shore species exhibit this phenomenon, whereas many others living under the same conditions are free of it.

*Volvulella* (*Paravolvulella*) *texasiana* HARRY, spec. nov.  
(Figure 21)

Shell small, cylindrical, translucent, grey, flecked irregularly with opaque, white areas (growth interruptions), the ends washed with reddish brown (iron stain). Aperture as long as the single visible whorl, but exceeded slightly by the tip of the spine. Side of whorl and aperture flattened, or in larger shells very slightly constricted by a vague, broad, medial sulcus. The diameter of the shell is the same at both ends in larger shells, but in very young shells the outline is inflated, suboval, with the greater diameter in the middle. Apical and basal ends gently curved. The spine is short, though usually broken, with a minute, bilobed appearance when seen in profile, and a minute, deep pit in the spine when seen from above. There is a narrow spiral band of roughened shell material around the base of the spine, its outer edge slightly above the shell surface. This tapers out along the upper, truncate part of the outer lip. Outer lip roundly quadrate above, its inner end meeting the columellar axis at a right angle; it is thin, acute throughout its length. The edge of the outer lip forward of the posterior sinus is almost in one

plane, but slightly more advanced in the direction of growth toward the base. Basal part of the lip strongly arched, not as advanced in the direction of growth as the outer. Columellar lip short, narrow, thickened, adnate, and without a lamella. No umbilicus, nor indentation in the umbilical area.

There are a few minute, closely and equally spaced spiral lines on the base, and similar, less prominent ones near the apical spine. Much fainter, wavy ones cover the middle part of the shell. These can only be seen at higher magnification.

**Holotype:** The holotype is USNM molluscan collection No. 678000, Height: 3.94 mm; Diameter 0.75 mm.

**Type locality:** Southeast of the base of the Bolivar Peninsula (east of Galveston, Texas), about 10 miles offshore, at 7 fathoms, Long. 94° 23' W, Lat. 29° 22' N. Two specimens were dredged there in December, 1965, and 4 more at the same place in January 1966, but no shells of this species were found in dredgings I examined from 54 other stations west and south of there, ranging from 3 to 18 fathoms. However, Mr. Charles Guice kindly provided specimens from three other stations (among 20 he examined) in the area. These yielded only one or two live animals per station. Two stations were at 7, and one at 9 to 10 fathoms. The species is evidently sparse and local.

*Volvulella texasiana* differs from *V. panamica* in its smaller size, in the slight medial constriction, and particularly in having a ridge around the spine. I could not find such a ridge in any specimens of *V. panamica* in the U. S. National Museum.

### Species from the Eastern Pacific

The species of the west coast of North America have been most recently reviewed by J. Q. BURCH (1947), with many locality and depth records. He gave two keys, taken from the notebook of the late Dr. Strong, which rely chiefly on presence of spiral sculpture and height-diameter ratios of the shell.

#### *Volvulella cylindrica* (CARPENTER, 1864)

*Volvula cylindrica* CARPENTER, 1864. Reprt. Brit. Assoc. Adv. Sci. 1863, p. 537 and 647. Not figured. Type locality: Santa Barbara, California. 1958, PALMER, Geol. Soc. Amer. Memoir 76: 240; pl. 25, figs. 1, 2 (holotype, Redpath Museum, No. 2364; extensive references)

*Volvulella cooperi* DALL, 1919. Proc. U. S. Nat. Mus. 56: 297 - 298. Not figured. Type locality: Scammon Lagoon, Lower California

*Volvulella callicera* DALL, 1919. Proc. U. S. Nat. Mus. 56: 299. Not figured. Type locality: U. S. Fish Comm. Sta. 2813, off Galapagos Islands, in 40 fathoms, coral sand

*Volvulella lowei* STRONG & HERTLEIN, 1937. Proc. Calif. Acad. Sci. ser. 4, 22: 164-165; plt. 35, fig. 2. Type locality: Puerto Escondido, Gulf of California. 1939, STRONG & HERTLEIN, Allan Hancock Pacific Exped. 2 (12): 190; plt. 18, fig. 1 (specimen from Panama)

This is an elongate species closely related to *Volvulella acuminata* and *V. persimilis*, but it grows larger than either, and the sides are somewhat more flattened than in those species. The apical end of the aperture is not sinuate as in *V. panamica*, and it extends to the top of the spine in the same plane as the latter. The apical end of the shell tapers more gently than in that species. Broadly spaced spiral striae are present at both ends, those at the apical end being less prominent and more easily worn off. Finer, more closely spaced spiral lines are present on the midpart of the whorl of at least some non-worn specimens.

The spine is variable in length, but tends to be short with a broad base. Figure 6 (USNM 212655, largest of 4 specimens; height 6.19 mm, diameter 2.00 mm) was dredged from 5½ fathoms off Lower California, and has a more tapering spine than the holotype figured by PALMER (1958). The range of this species is generally cited as Vancouver Island to the Gulf of California

(PALMER, 1958), but the U. S. National Museum has a lot of 2 shells (USNM 509036) from Panama, collected by Zetek, which are quite typical of this species.

Although GRANT & GALE (1931) and others have recognized *Volvulella cooperi* DALL as distinct, I think it is only an aspinous variant of this species. Figure 7 (USNM 105501, Scammon Lagoon, Lower California) was drawn from the next to smallest of 4 cotypes of *V. cooperi* DALL. All 4 are badly worn. Weak spiral lines are present on the bases of 2, but none could be found elsewhere. DALL evidently gave the measurements of the largest shell (9.5 mm long, diameter 3.6 mm) but both larger specimens are so badly worn as to make them poor choices for a type specimen. The one illustrated (Figure 7) is here selected as *lectotype*. It is only slightly worn, but the lip is badly broken.

Measurements of the cotypes are:

	Height	Diameter
Paratype:	9.68	3.61
Paratype:	7.61	2.58
Lectotype:	6.45	2.32
Paratype:	5.29	2.06

Figure 8 (USNM 194176b) is drawn from the smallest of 3 cotypes (here designated *lectotype*) of *Volvulella*

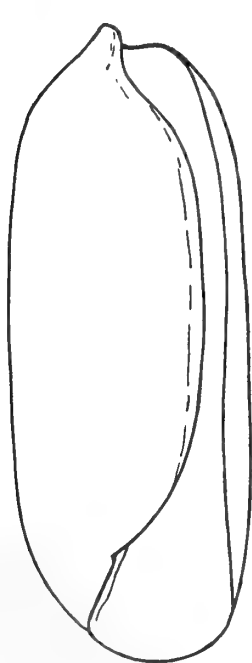


Figure 18

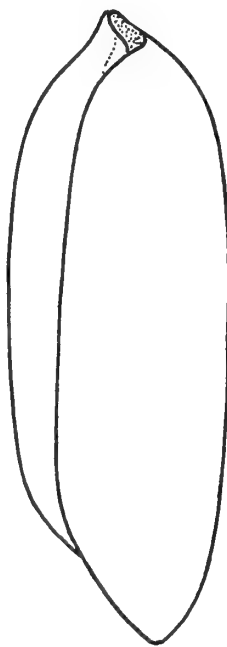


Figure 19

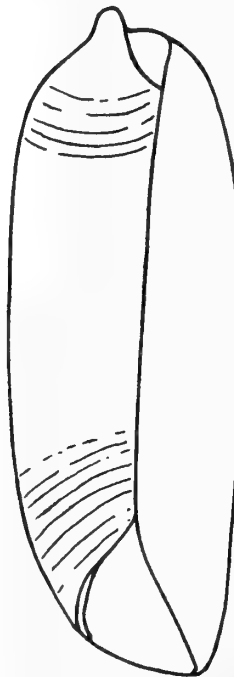


Figure 20



Figure 21

Figure 18: Lectotype of *Volvulella panamica* DALL. 4.25 mm high

Figure 19: Side view of the same shell as in Figure 18.

Figure 20: Paratype of *Volvulella tenuissima* WILLET. 4.5 mm high

Figure 21: Holotype of *Volvulella texasiana* HARRY, spec. nov. 3.94 mm high

*callicera* DALL. All are bleached, with sand grains lodged in the aperture and the upper part of the lip slightly broken. But the sculpture is evident and quite typical: broadly spaced spiral lines at both ends, with finer, closely spaced lines in the middle. DALL (1919) gave the measurements: length 3.5 mm, diameter 1 mm.

My measurements of largest and smallest cotypes are:

	Height	Diameter
Paratype:	4.31	1.38
Lectotype:	3.06	0.94

Figure 9 (USNM 267574, Head of Conception Bay, Gulf of California) is drawn from a specimen set aside as "figured type" of a species to be named by BARTSCH. I can not find that he ever published it, although a manuscript name was present on several lots in the U. S. National Museum. They are a mixture of *Volvulella cylindrica* and *V. panamica*, all from the Gulf of California. The dimensions of the specimen drawn are: height 7.88 mm, diameter 1.69 mm.

I have seen no authentic specimens of *Volvulella lowei* STRONG & HERTLEIN, but judging from the figures and description, it is a poorly spined form of *V. cylindrica*.

#### *Volvulella californica* DALL, 1919

*Volvulella californica* DALL, 1919. Proc. U. S. Nat. Mus. 56: 299-300. Not figured. Type locality: off Santa Rosa Island, California, in 53 fathoms, sandy mud. 1927, OLDROYD, Marine shells west coast, 2 (1): 34; pl. 2, fig. 11 [poor]

Figure 12 (USNM 211303) is drawn from the larger (here designated **lectotype**) of 2 complete cotypes. A third cotype has the body whorl badly broken. The specimens are slightly weathered, so that there is no trace of finer spiral lines which may be present on unworn specimens. About 8 widely spaced spiral lines are present on the base of the lectotype, which shows none near the apex. Apical spirals are present in the complete paratype, however. The profile of the shell is broadly arched, with the greatest diameter in the middle. The spine is of moderate length. This may be the West Coast counterpart of *Volvulella recta*, but it lacks any trace of transverse striae near the apex. It is distinctly more cylindrical than that species. The only specimens I found in the U. S. National Museum which could certainly be referred to this species were those of the type series. Possibly this is only a growth stage of *V. cylindrica*. However, BURCH (1947) cites it from 6 stations, between Santa Cruz, California, and Todos Santos Bay, Lower California, ranging in depth from 30 to 298 fathoms. Measurements of 2 non-broken cotypes (*cf.* DALL, 1919, who stated "length 4; diameter 1.7mm") are:

	Height	Diameter
Lectotype:	4.44	2.00
Paratype:	3.63	1.56

#### *Volvulella catharia* DALL, 1919

*Volvulella catharia* DALL, 1919. Proc. U. S. Nat. Mus. 56: 298. Not figured. Type locality: U. S. Fish. Comm. Sta. 2794 in Panama Bay, in 62 fathoms, sand

Figure 14 (USNM 211784) is a drawing of the slightly more globose of the 2 non-broken of 4 cotypes, all of which are about the same size and slightly worn. It is here designated **lectotype**. It measures: height 2.75 mm, diameter 1.44 mm (DALL, 1919, stated: "length of shell, 2.75; diameter, 1.8 mm"). This is the West Coast counterpart of *Volvulella paupercula* (WATSON), and the limited series at the U. S. National Museum (only one other lot, 194976a, Galapagos Islands, 40 fathoms) leaves room for doubt about whether it is distinct from that species. It may not grow as large as the eastern one. A few widely spaced spiral lines are present on the base, but none could be seen on the apex, nor over the midregion of the shell (worn off?). It is very thick shelled, like its eastern relative, and there is no spine, but a minute, rimate umbilicus at the apex.

#### *Volvulella (Paravolvulella) panamica* DALL, 1919

*Volvulella panamica* DALL, 1919. Proc. U. S. Nat. Mus. 56: 298. Not figured. Type locality: Panama Bay at Sta. 2799, in 29½ fathoms. 1937, STRONG & HERTLEIN, Proc. Calif. Acad. Sci. ser. 4, 22: 164; pl. 35, fig. 3

*Volvulella tenuissima* WILLETT, 1944. Bull. So. Calif. Acad. Sci. 43: 71-72; pl. 4, fig. 1. Type locality: Off Redondo, California, in 75 fathoms

Figures 18 and 19 are drawn from the single shell in a separate vial of USNM 212654, height 4.25 mm, diameter 1.56 mm (DALL stated: "length 4.25, diameter 1.75 mm") which is here designated **lectotype** of *Volvulella panamica* DALL. Another vial with the same catalogue number contains a large series of specimens, all slightly weathered. The lectotype has traces of strong spiral lines at both ends, and finer, closely spaced ones over the middle. This is the most distinctly cylindrical of the West Coast species, with the apical end abruptly rounded, the spine short and blunt, and the apical end of the lip deeply sinuate by not being as advanced in the direction of growth as the rest of the lip. The apical part of the lip appears truncate, not extending to the tip of the spine, although the parietal wall actually forms the latter (Figure 19).

Figure 20 is drawn from the larger of 2 perfect (of 3) paratypes of *Volvulella tenuissima* WILLETT (USNM 573516, height 4.50 mm, diameter 1.63 mm). The specimens were evidently collected alive, and show pronounced sculpture, with brown iron stain on the ends. The spiral lines on the ends are very closely spaced, but I suspect this varies within the species. It is notable that WILLETT (1944) compared his new species only with *V. cylindrica* and did not mention *V. panamica*. This species ranges from off Redondo, California, to Panama, and is abundantly represented in the U. S. National Museum from the Gulf of California. There is no apical spiral ridge in any of the numerous specimens seen of *V. panamica*, such as that present in *V. texasiana*.

### Species of the Indian and Western Pacific Oceans

Listed below in alphabetical order are all trivial names I have found of living species of this genus in the western Pacific and Indian Oceans. This includes 3 which have been attributed to the genus, but probably belong elsewhere, and one which was described as *Cylichna* which probably is a *Volvulella*. Further studies on this genus in the Indo-Pacific area should review all those described as *Cylichna*, for possibly others originally so allocated belong here. Populations very similar to *V. acuminata* are widely distributed in these oceans. Whether they are specifically distinct from that species is a moot question. But one of them, *V. pia*, was described from the southern tip of Africa and might as well be relegated to the Atlantic as to the Indo-Pacific fauna. The other 3 species groups of American shores are found in these oceans also. I have made a guess regarding the Atlantic analogue of each nominal species listed below. The species described by A. ADAMS in 1862 are particularly difficult to recognize, being described in a few lines of Latin, not figured, and with no measurements. Some authors have named new species if they found them at a distance, or of an age, remote from any species previously described. Insufficient specimens from the Indo-Pacific have prohibited decisions on the validity of these, but I have pointed out such opinions on synonymy as have been found.

*acutaeformis* YOKOYAMA, 1922 (*Volvula*), p. 26, pl. 1, fig. 9. Type locality: fossil, from Shito, Japan (of *V. recta* group; he compared it to *V. minuta* BUSH). KURODA & HABE (1952) attributed it to the recent fauna of Japan, and HABE (1954) declared it a synonym of *V. ovulina* ADAMS.

*angustata* A. ADAMS, 1850 (*Bulla* (*Volvula*)), p. 596, pl. 125, fig. 153. Type locality: Cagayan, Mindanao (Philippines), 25 fathoms (of *V. acuminata* group).

*aomoriensis* NOMURA, 1939 (*Rhizorus*), p. 26, pl. 2, figs. 9a, 9b. Type locality: Japan, numerous localities cited, 30 fathoms (of *V. acuminata* group). HABE (1955) called this a synonym of *V. radiola* ADAMS.

*artiaperta* YAMAKAWA, 1911 (*Volvula*), p. 50, pl. 11, figs. 33 - 36. Type locality: fossil, Japan [original not seen]. KURODA & HABE, 1952, cited this living, and HABE, 1955, said it is a synonym of *V. eburnea* ADAMS.

*attenuata* A. ADAMS, 1862 (*Volvula*), p. 155, not figured. Type locality: Tsu-Sima (Japan), 26 fathoms. (Probably of *V. recta* group).

*compacta* MELVILL, 1906 (*Volvula*), p. 79, pl. 7, fig. 26. Type locality: not indicated, evidently Persian Gulf or Gulf of Oman. No depth given (of *V. paupercula* group).

*cylindrella* A. ADAMS, 1862 (*Volvula*), p. 155, not figured. Type locality: Mino-Sima (Japan), 63 fathoms (of *V. acuminata* group).

*eburnea* A. ADAMS, 1850 (*Bulla* (*Volvula*)), p. 597, pl. 125, fig. 155. Type locality: China Sea. KURODA & HABE (1954, pl. 2, fig. 11) provided a photograph of a specimen supposedly identified by ADAMS, now in the Redpath Museum (probably of *V. recta* group).

*exilis* THIELE, 1925 (*Volvula*), p. 316, pl. 31, fig. 25. Type locality: Padang, Sumatra (a poorly spined specimen of the *V. acuminata* group).

*flavotincta* MARTENS, 1903 (*Volvula*), pp. 130-131, pl. 5, fig. 21. Type locality: East Africa, (Valdivia) station 270, in Gulf of Aden, 1840 m deep (possibly of the *V. paupercula* group).

*fortis* THIELE, 1925 (*Volvula*), p. 238, pl. 31, fig. 23. Type locality: 0° 30.2' N Lat., 97° 59.7' E Long., 132 m depth, "Nias-Süd Kanal" (South of Sumatra) (probably of *V. recta* group; it has transverse ridges at the base of the spine).

*granulum* PHILIPPI, 1851 (*Bulla*), pp. 63-64; not figured. Type locality: China. This is probably the "*granulum* PHILIPPI" listed under *Volvula* by H. & A. ADAMS (1854: 14). I agree with PILSBRY (1893: 309), who placed it in *Cylichna*.

*kinokuniana* HABE, 1946 (*Rhizorus*), p. 186, not figured. The description is in Japanese. KURODA & HABE (1954, pp. 8-9, pl. 2, fig. 15) illustrated a shell in the Redpath Museum, supposedly received from A. ADAMS, under the unpublished name *Volvula solidula* A. ADAMS. They declared this is *Volvuella* [sic] *kinokuniana* HABE and note the species is from "deep bottoms of Tosa Bay, Shikoku, and also off Wakayama Pref., Honshu (Japan)" (of *V. paupercula* group).

*lenis* THIELE, 1925 (*Volvula*), p. 238, pl. 31, fig. 22. Type locality: 0° 39.2' S Lat., 98° 52.3' E Long., 750 m

depth, near Siberoet Island (South of Sumatra) (of *V. paupercula* group).

*mecynte* MELVILL, 1912 (*Cylichna*), p. 253, pl. 11, fig. 15. Type locality: Persian Gulf, Ormara. The single specimen was spineless, but seems to be a *Volvulella* of the *V. texasiana* group.

*minutissima* THIELE, 1925 (*Volvula*), p. 316, pl. 31, fig. 24. Type locality: (*l. c.*, p. 254): Padang, Sumatra (of *V. recta* group; it has transverse ridges at the base of the spine).

*mucronata* PHILIPPI, 1849 (*Bulla*), p. 22, not figured. Type locality: Red Sea at Aden. This is probably the *mucronata* PHILIPPI listed by H. & A. ADAMS (1854: 14) under *Volvula*, and cited by A. ADAMS (1862). I agree with PILSBRY (1893: 191), who placed it in *Tornatina*.

*nesentus* FINLAY, 1926 (*Rhizorus*), p. 438; new name for *Volvulella reflexa* SUTTER, 1913 (p. 529, pl. 23, fig. 2; Recent of New Zealand, non *Cylichna reflexa* HUTTON, 1886, fossil, Miocene of New Zealand).

*opalina* A. ADAMS, 1862 (*Volvula*), p. 154, not figured. Type locality: Mino-Sima, 63 fathoms (Japan) (possibly of *V. acuminata* group).

*ovulina* A. ADAMS, 1862 (*Volvula*), p. 155, not figured. Type locality: Mino-Sima, 63 fathoms (Japan) (probably of *V. recta* group).

*parata* IREDALE, 1936 (*Volvulella*), p. 332. New name for a figured specimen HEDLEY (1903: 394, fig. 109) had identified as *V. rostrata* A. ADAMS. DELL (1956) argued convincingly that this is merely a synonym of *V. rostrata*.

*pia* THIELE, 1925 (*Volvula*), p. 238, pl. 31, fig. 21. Type locality: 34° 51' S Lat., 19° 37.8' E Long., 80 m, near Cape Agulhas (Southern tip of Africa) (similar to *V. acuminata*, of which it may be a synonym).

*radiola* A. ADAMS, 1862 (*Volvula*), p. 155, not figured. Type locality: Tabu-Sima, 25 fathoms (Japan). The description suggests it belongs to the *V. acuminata* group, but KURODA & HABE (1954, pl. 2, figs. 3 and 4) published a photograph of a shell in the Redpath Museum supposedly from A. ADAMS, which resembles the *V. texasiana* group.

*rostrata* A. ADAMS, 1850 (*Bulla* (*Volvula*)), p. 596, pl. 125, fig. 154. Type locality: Port Lincoln (Australia) (probably of *V. recta* group).

*spectabilis* A. ADAMS, 1862 (*Volvula*) p. 154, not figured. Type locality: Tabu-Sima, 25 fathoms (Japan) (probably *V. acuminata* group).

*striatula* A. ADAMS, 1850 (*Bulla* (*Volvula*)), p. 597, pl. 125, fig. 156. Type locality: China Sea (possibly of *V. texasiana* group).

*sulcata* WATSON, 1883 (*Cylichna* (*Volvula*)), p. 326, not figured. Type locality: Torres Strait, North of Australia. WATSON, 1886, p. 670, pl. 50, fig. 6 (of *V. recta* group).

*tokunagai* MIKIYAMA, 1927 (*Volvulella acuminata* sub-spec.), pp. 144-145, not figured. New name for the Japanese Pleistocene fossil *Cylichna acuta* "D'ORB." TOKUNAGA, 1906, Journ. Coll. Sci. Univ. Tokyo 21 (2): 32, pl. 2, fig. 13, not *Bulla acuta* D'ORBIGNY. NOMURA (1939: 26) elevated this subspecies to specific rank, and cited it living at several localities in Japan. NOMURA's figures (*l. c.*, pl. 2, figs. 8a, 8b) show it belongs to the group of *V. recta*.

*tragula* HEDLEY, 1903 (*Volvula*), p. 395, text fig. 110. Type locality: 63-75 fathoms, off Port Kembla, Australia (resembles *V. recta*; there are coarse spiral ridges at the base of the spine shown in the figure but not mentioned in the text).

*truncata* DELL, 1956 (*Volvulella*), p. 146, pl. 20, figs. 211, 212. Type locality: 260 fathoms, Chatham Islands, New Zealand (possibly of *V. texasiana* group).

## SUMMARY

*Volvulella*, a genus of minute snails, is world wide in distribution in the tropics and warm temperate waters, ranging from a few to many meters depth. They are rare and local, with few distinctive characters to distinguish species. Four species groups are recognized, with analogous species in the various major oceans. Possibly only one species group occurs in the eastern Atlantic, but all 4 groups are represented in the western Atlantic and eastern Pacific, and in the Indo-Pacific area. *Volvulella* NEWTON, 1891, is accepted as the correct name of this genus, of which *Bulla acuminata* BRUGUIÈRE is the type species by designation of A. ADAMS, 1862. *Paravolvulella*, new sub-genus is established with *V. (P.) texasiana*, spec. nov., designated as type. Six unfigured type specimens of nominal species of DALL from the east and west coast of North America are illustrated. A catalogue of 30 nominal species from the Indo-Pacific area indicates to which of the 4 recognized species groups each may belong.

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## Relationship between *Penitella penita* (CONRAD, 1837) and Other Organisms of the Rocky Shore

BY

JOHN W. EVANS

Department of Biology

Memorial University of Newfoundland, St. John's, Newfoundland, Canada

(Plate 16)

EVANS (1949) AND LEWIS (1953), IN THEIR STUDIES OF the English coast, refer to the intertidal animals which live in holes, crevices and other areas, where they are protected from the sun and from desiccation, as the "cryptofauna."

KÜHNELT (1951) suggested the following terminology to describe the fauna of hard marine bottoms: animals living on the surface of rock occupy the epilithion, those partially embedded occupy the mesolithion, and those wholly embedded occupy the endolithion. Since these terms carry more information than 'cryptofauna', they will be used in this paper. The endolithic community is that group of animals inhabiting the endolithion.

The cryptofauna of EVANS (1949) and LEWIS (1953) included a wide assemblage of relatively delicate, mostly filter feeding animals, such as: hydroids, anemones, tunicates, sponges and bryozoans. These authors observe that the cryptofauna is present primarily in areas of exposed limestone which is readily attacked by borers, such as the clam *Hiatella* sp., the polychaete *Polydora ciliata* (JOHNSTON, 1838) and the sponge *Cliona celata* GRANT. The rough surface produced by these borers serves to hold water during low tide periods and provide homes for nestlers. The large burrows of *Hiatella* were usually occupied by a variety of anemones.

*Penitella penita* is the most numerous and most widely distributed rock borer along the eastern Pacific coast (COAN, 1964; TURNER, 1955). It is found both subtidally and intertidally, on exposed coasts and in protected bays wherever rock of suitable hardness and composition is available (LLOYD, 1897). The boring activity of *P. penita* is primarily responsible for developing the endolithion as a possible habitat. The conical holes drilled by this animal form dwellings for a large number of nestling animals which move into the empty burrows after the pholads' death.

The following observations were made in the course of a general ecological study of *Penitella penita*. The principal area of study was on two intertidal benches near Fossil Point in Coos Bay, Oregon. Observations were also made on animals collected from South Jetty, a jetty protecting the entrance to Coos Bay, and from the north side of Cape Blanco, Oregon.

### Relationship between *Penitella penita* and Organisms of the Epilithion

Once the young *Penitella penita* is well established in the rock, there appears to be little interaction between it and organisms of the epilithion, since pholads derive their food and oxygen from the overlying water. However, surface encrustations appear to control to a certain extent the success of settlement.

Settlement on cleared surfaces facing approximately southeast was compared with surfaces facing northeast (Table 1). The former surfaces quickly developed a heavy coating of algae, presumably from the greater exposure to light, whereas the latter surfaces remained relatively free of algae but received a heavy settlement of *Balanus crenatus* BRUGUIÈRE, 1789. The density of *Penitella penita* was greater on the northeast barnacle-encrusted surfaces than on the algae-coated surfaces. This indicates that conditions suitable for settlement of pholads are similar to those for *B. crenatus*. It also seems likely that either algal cover or high light intensity inhibits settlement of both barnacles and pholads. (See NAGABHUSHANAM, 1959 c, 1960; ISHAM *et al.* 1951 on taxis of marine larvae.)

Table 1

Settlement Density as Related to Surface Direction

Area (cm <sup>2</sup> )	Number of pholads	Southeast Face algae covered	Northeast Face barnacle covered	Exposure time (months)	Animals per 100 cm <sup>2</sup>
50	44		×	2½	88.0
70	3	×		2½	4.3
190	21		×	6½	11.0
350	16	×		6½	4.6
800	353		×	8	44.1
800	157	×		8	19.6

### Interference Between Barnacles and Newly Settled Pholads

A certain amount of interference occurs during, and for a short time after settlement between young pholads and barnacles. If a pholad enters the rock close to newly-settled barnacles, it runs a risk of having its entrance occluded by the laterally expanding base of the barnacle. The pholad siphon, however, appears to be able to dissolve the edge of the barnacle and thus distort its symmetry (see Plate 16).

Examples of barnacles completely occluding burrow entrances were also found. The enclosed pholad was, of course, dead. It is not known whether the barnacle covered the entrance hole before or after the death of the clam.

*Botula californiensis* (PHILIPPI, 1847), inhabiting the mesolithion, interferes with *Penitella penita* by settling in burrow entrances or boring laterally into burrows. The interference caused is sometimes enough to kill *P. penita*.

The only animal that has been observed to prey on *Penitella penita* at both Fossil Point and South Jetty is the flatworm *Stylochus* sp. PEARSE & WHARTON (1938) report that *S. inimicus* (PALOMBI, 1931) is a predator of oysters. *Stylochus* can enter remarkably narrow pholad holes. For example, a flatworm about 32 mm by 16 mm

was found inside a burrow, the entrance of which was only 1.8 mm in diameter. *Stylochus* consumes the flesh of *Penitella* and leaves the valves in place. It often lays eggs on the inside of the burrow and valves.

The empty burrows left after the death of pholads are filled by a number of nestling animals, which make up the remainder of the endolithic community.

At Fossil Point the empty burrows become filled with sand and mud. Most of the silt-filled burrows are occupied by a terebellid worm, *Thelepus* sp., and its commensal scale worm, *Halosydna brevisetosa* KINBERG, 1855. *Thelepus* appears to extract CaCO<sub>3</sub> from the pholad valves and deposit at least part of it as a chalky layer on the inside of its parchment burrow. The valves of the dead pholad are gradually dissolved completely.

Occasionally bivalves, such as *Tresus nuttallii* (CONRAD, 1837), *Petricola carditoides* CONRAD, 1837, *Macoma nasuta* (CONRAD, 1837) and *Irus lamellifer* (CONRAD, 1837) are found nestling in pholad burrows at Fossil Point. ADDICOTT (1963) found fossil *Tresus nuttallii* nestling in *Penitella penita* burrows in rock of late Pleistocene age.

Just as the epifauna on exposed rocky shores is richer and more varied than in the muddy bays, so too the endolithic community in rocks exposed to the open ocean is more diverse.

Empty burrows exposed to the open ocean are very seldom mud or sand filled. No attempt was made to compile a complete list of organisms occupying this habitat, but the obvious forms were collected and identified (Table 2). On the open coast, 25 taxa were observed as compared with 9 at Fossil Point.

## DISCUSSION

The position of the pholad in the littoral community can be compared to that of the woodpecker in the forest community. Both are capable of boring holes in substrates that cannot be worked by other members of the community. In both cases the burrow is used only once, by its originator, and is thereafter left open for a variety of hole or crevice dwellers. In the absence of marine rock borers the endolithic community will not develop. The variety of animal species whether epi-, meso-, or endolithic, on the rocky shore is greatly enhanced by the presence of borers.

Table 2

## Nestlers Inhabiting Vacated Pholad Burrows

Open Coast	Fossil Point	Major Taxa	Species
×		Coelenterata	<i>Anthopleura artemisia</i> (PICKERING in DANA, 1848)
	×		<i>Diadumene leucolena</i> (VERRILL, 1866)
×	×	Annelida	<i>Thelepus</i> sp.
×	×		<i>Halosydna brevisetosa</i> KINBERG, 1877
×			<i>Serpula</i> sp.
×			<i>Eupolymnia heterobranchia</i> (JOHNSON)
×			<i>Ramex</i> sp.
×			<i>Pista elongata</i> MOORE, 1909
×			<i>Schizobranchia</i> sp.
×			<i>Distylia</i> sp.
×			<i>Idanthersus</i> sp.
×			<i>Demonax</i> sp.
×		Sipunculoidea	<i>Phascolosoma agassizii</i> KEFERSTEIN, 1866
×			<i>Dendrostomum pyroides</i> CHAMBERLIN, 1919
×		Crustacea	<i>Pachycheles rudis</i> STIMPSON, 1859
×			<i>Oedignathus inermis</i> (STIMPSON, 1860)
×			<i>Spirontocaris palpator</i> (OWEN, 1839)
×			<i>Betacus harfordi</i> (KINGSLEY, 1878)
×		Mollusca	<i>Crepidula nummaria</i> GOULD, 1846
	×		<i>Irus lamellifer</i> (CONRAD, 1837)
×			<i>Trimusculus reticulatus</i> (SOWERBY, 1835)
	×		<i>Tresus nuttallii</i> (CONRAD, 1837)
	×		<i>Petricola carditoides</i> CONRAD, 1837
×	×		<i>Macoma nasuta</i> (CONRAD, 1837)
×			<i>Protothaca staminea</i> (CONRAD, 1837)
×			<i>Entodesma saxicola</i> (BAIRD, 1863)
×	×		<i>Saxicava</i> sp.
×			<i>Kellia suborbicularis</i> (MONTAGU, 1804)
	×		<i>Botula californiensis</i> (PHILIPPI, 1847)
×		Urochordata	<i>Pyura haustor</i> (STIMPSON, 1864)

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## Explanation of Plate 16

The distorted edge of the central barnacle is caused by the young  
pholad siphon which emerged from the hole at the right. The siphon  
may have the ability to dissolve CaCO<sub>3</sub>.





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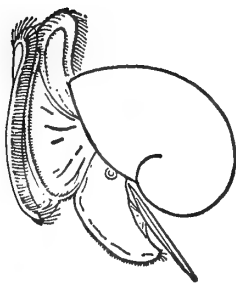
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# Freshwater Mollusks Collected by the United States and Mexican Boundary Surveys

BY

DWIGHT W. TAYLOR

Department of Zoology  
Arizona State University, Tempe, Arizona 85281

TRACING THE TYPE LOCALITIES of several freshwater mollusks led to a review of collections made by the two commissions that surveyed the boundary between the United States and Mexico, in 1849 - 1855 and 1891 - 1894. The present paper summarizes the species collected, relocates the localities as precisely as possible, and corrects previously published identifications. I have emphasized study of specimens from west of the continental divide, but the summary of published information concerning all of the collections is intended to be complete.

The mollusks collected during the first boundary survey have never been treated as a group before. Indeed, malacological literature gives no indication that they are a result of that survey. DALL (1896) reported on collections by the second survey, but as his paper omitted some specimens and gives erroneous localities for others I have thought it worthwhile to review collections by both boundary expeditions.

A general account of the boundary surveys, as well as other early explorations in the west, was published by WALLACE (1955). This summary is briefer and more accessible than the official reports of the boundary commissions. It also provides historical background and comments on the numerous lighter aspects - strange as it may seem - of these surveys.

Geographic coordinates in the form "NH 14-5 C-5" designate a 15-minute quadrangle as explained more fully by TAYLOR (1966a: 28). The letters and first number (NH 14) are part of the system of reference of the "International Map of the World, 1 : 1 000 000" published under auspices of the United Nations Cartographic Office; they designate a quadrangle 4 degrees of latitude by 6 degrees of longitude. "NH 14-5" designates a subdivision, 1 degree by 2 degrees, in the system used by the U. S. Army Map Service and U. S. Geological Survey for maps at scale 1 : 250 000.

## ABBREVIATIONS

Names of Institutions housing specimens cited herein have been abbreviated as ANSP, Academy of Natural Sciences of Philadelphia, Pennsylvania; MCZ, Museum of Comparative Zoology, Cambridge, Massachusetts; and USNM, U. S. National Museum, Washington, D. C.

### First Boundary Survey (1849 to 1855)

One of the series of Commissioners of the United States and Mexican Boundary Survey was J. R. Bartlett, who published a voluminous account (BARTLETT, 1854) of his travels together with a map showing his route. Dr. T. H. Webb, Surgeon and Secretary to the survey party, collected mollusks at localities I have discussed below. The survey was completed by W. H. Emory, whose official account (EMORY, 1857) includes no mention of mollusks except in the report by PARRY (1857), and no indication that any mollusks were collected.

BARTLETT's account (1854) is precise enough to permit relocation of several molluscan type localities. These are listed in the order of collection.

1. Llano River, Texas. Type locality of *Lampsilis bracteata* (GOULD, 1855 b) and *Quadrula petrina* (GOULD, 1855 b). Collected October 18, 1850 (BARTLETT, 1854, v. 1, p. 64), probably not far from the present crossing of U. S. highway 87 southeast of Mason, Mason County, Texas (NH 14-5 C-5).

JOHNSON (1964) illustrated type material of the two species from this locality: plt. 31, fig. 4, holotype (MCZ 169291) of *Quadrula petrina*; and plt. 31, fig. 5, lectotype (USNM 84966) of *Lampsilis bracteata*.

2. Comanche Creek, Texas. Type locality of *Anodonta imbecillis horda* GOULD (1855 b). Collected October 18,

1850 (BARTLETT, 1854, v. 1, p. 65), 9 miles from the preceding locality, close to the present site of Mason, Mason County, Texas (NH 14-5 C-5).

JOHNSON (1964: 88) selected as lectotype the specimen (British Museum, uncatalogued) illustrated by SOWERBY (1867, plt. 18, fig. 66) as *Anodon hordeum*. Subsequently the measured holotype has been found in Gould's collection at the U. S. National Museum (USNM uncatalogued) by R. I. Johnson (personal communication, March 1967).

3. Pecos River, Texas. One of two original localities of *Physa humerosa* GOULD (1855 a). Bartlett's party crossed the Pecos October 29, 1850, and then traveled northward along the west side until November 5 (BARTLETT, 1854, v. 1, pp. 93 - 109). Horse-head Crossing is a plausible site of collection; it is near the bridge on U. S. highway 67-385 over the Pecos, where the river forms the boundary between Crockett and Pecos Counties, Texas (NH 13-3 A-2).

Collections made by Dr. Webb in Arizona, Baja California, and California might have been made en route to San Diego, California, in late 1851 and early 1852, or (more probably) on the return journey eastward in 1852. The report by WEBB to BARTLETT (1854, v. 2, pp. 1 - 5), and BARTLETT's (1854, v. 2, p. 550) statement about Webb's collections, indicate loss of baggage and physical hardships on the westward trip.

4. Colorado Desert or Cienega Grande, Baja California and California. Type locality of *Biomphalaria gracilentia* (GOULD, 1855 a), the type specimen collected by Webb. GOULD also cited Webb as one of the collectors of original material of *Physa humerosa*, *Planorbis ammon*, and *Tryonia protea*, but whether Webb or W. P. Blake collected the type specimen is not determinable and does not matter in this case. Bartlett and Webb crossed the Colorado Desert to Fort Yuma June 5 to 9, 1852 (BARTLETT, 1854, v. 2, pp. 129 - 152).

5. "River Gila, near San Diego" (seemingly one locality) was cited by GOULD (1862: 216) as the source of *Physa virgata*. "River Gila, and near San Diego" (evidently two localities) was the original form (GOULD, 1855 a). I have found only one San Diego near the Gila River; it was on the route traveled by Dr. Webb and is probably the type locality. The name was given by Father Garcés November 12, 1775, to a group of Indian rancherías that Coues (1900, v. 1, p. 117) identified as being most likely at Kenyon's. This was a stage station on the overland mail route, about in the NE $\frac{1}{4}$  T. 5 S., R. 7 W., Maricopa County, Arizona (NI 12-7 A-4).

If San Diego is taken as a second locality, additional to the Gila River, there are two possible identities. One is the city in southern California, where Bartlett and Webb

stayed in the spring of 1852. The other was on the Rio Grande in New Mexico, upstream from El Paso. Dr. Webb crossed the river here at least three times; in the spring of 1851, en route to and from the copper mines at Santa Rita del Cobre (BARTLETT, 1854, v. 1, pp. 178 - 181), and on April 27, 1851, when the Survey party as a whole traveled westward (BARTLETT, 1854, v. 1, p. 215).

JOHNSON (1964, plt. 44, fig. 5) illustrated his lectotype (MCZ 72995) of *Physa virgata*. I have examined one series of paratypes (USNM 27966), but not the specimen (ANSP 17244a) identified by H. B. BAKER (1964) as the holotype.

6. Bartlett mentioned collecting mollusks only once, and strangely the specimens seem never to have been recorded in scientific writings, nor has anyone else collected mollusks there. The entry is for August 6, 1852, 8 miles west of Janos, Chihuahua: "In the afternoon we crossed a fine clear stream, thirty to forty feet wide and about two deep, occasionally expanding into ponds twice that depth, and encamped on the opposite bank where there was excellent grass. This stream is a branch of the river which passes Janos and Correlitos, the latter being known both as the San Miguel and as the Casas Grandes River. Like other streams in Mexico, it takes the names of the several towns it passes. In it we caught a sufficient number of trout to give us all a meal. We also collected specimens of unios, which abound here . . ." (BARTLETT, 1854, v.2, p. 337). The locality is shown on the American Geographical Society's Map of Hispanic America, 1 : 1 000 000, Sonora sheet (1937) as Arroyo del Salto del Ojo (NH 12-6 D-2).

7. Ojo Caliente, Chihuahua. "*Cochliopa*" *chihuahua* (PILSBRY, 1928) was described from 4 shells found on an herbarium sheet of *Myriophyllum heterophyllum* in the Academy of Natural Sciences of Philadelphia. The specimens were collected by George Thurber, October, 1852. Thurber was botanist on the first Boundary Survey (BARTLETT, 1854, v. 1, p. 47), the party camping at Ojo Caliente on October 16, 1852 (BARTLETT, 1854, v. 2, p. 410). The narrative gives the location as 12 miles south of Carrizal and a mile north of the "river Carmen" (now Río del Carmel); these distances and the map by BARTLETT (1854) are consistent with the place shown as Ojo Caliente de Santa Rosa on the American Geographical Society's Map of Hispanic America, 1 : 1 000 000, Chihuahua sheet (1934) (NH 13-4 B-3).

For the convenience of anyone trying to relocate the type locality on the ground, I quote Bartlett's description:

"Ojo Caliente is a spring which rises from the plain about one hundred and fifty yards from the base of a rocky hill. Its temperature is nearly the same as that of the atmosphere. A small pool about one hundred and twenty feet in circuit, and from three to four deep, is here

formed, with a sandy bottom, from which warm water bubbles up in many places; this water has an outlet through a small creek into the river Carmen, in which creek some fish were taken and preserved for specimens" (BARTLETT, 1854, v. 2, p. 410).

8. *Puntiagudo*, Nuevo Leon. The type locality of *Uniomermus tetralasmus manubius* (GOULD, 1855 b) is "Chihuahua, 60 miles from Camp Ringgold." According to the itinerary this locality would have been about 30 miles southwest of Mier, Tamaulipas, at the village of *Puntiagudo* where Bartlett and Webb passed December 18, 1852. BARTLETT (1854, v. 2, p. 507) noted "A small stream passes here, one of the tributaries of the Alcantra."

Neither of the names Alcantra or *Puntiagudo* appears on modern maps. The map by ROEMER (1935; first published in 1849 and dating to 1845-1847) shows the "Aclantro R." flowing into the Rio Grande near Mier, evidently the Río Alamo of modern usage.

*Puntiagudo* is identified by WISLIZENUS (1848: 78) as "a burnt village on a creek, which is one of the headwaters of the Alamo," 15 miles northeast of Cerralvo, Nuevo Leon, and 30 miles southwest of Mier, Tamaulipas. This description and WISLIZENUS' map show that the site of *Puntiagudo* is about 3 miles northeast of the modern town General Treviño, Nuevo Leon, on the Río Agualeguas, a tributary of Río Alamo (NG 14-5 B-6).

JOHNSON (1964, plt. 32, fig. 5) illustrated the holotype (MCZ 169447) of *Uniomermus tetralasmus manubius*.

9. *Sphaerium nobile* (GOULD, 1855 b) was described from "near San Pedro, California," a locality known now to be in error. A possible locality might seem to be the San Pedro River drainage of southern Arizona, crossed by Bartlett and Webb several times. Yet a paratype of *S. nobile* (USNM 11592) seems to me to be *S. striatinum* (LAMARCK) and not *S. triangulare* (SAY), the only similar species in Arizona. Hence a "San Pedro" farther east is most likely, perhaps San Pedro Springs at San Antonio, Texas, where Bartlett and Webb camped September 27 to October 9, 1850 (BARTLETT, 1854, v. 1, pp. 38 - 48).

I found no explicit statement about the scope or final disposition of Webb's collection of mollusks. BARTLETT (1854, v. 1, p. viii) mentioned that zoological collections were divided between the Smithsonian Institution and Boston. The Tenth Annual Report of the Smithsonian Institution, for 1855 (p. 47) mentions "The fruits of the travels of Dr. Thos. Webb, in the more western portions of northern Mexico," but does not refer explicitly to shells. The *Proceedings of the Boston Society of Natural History* for December 21, 1853 (4: 395) referred to the "collection of Dr. Webb, now on deposit with the Society," from which the shells were referred to Dr. Gould. Whether these were all of Webb's collections, and whether addition-

al locality data will turn up, depends on unpublished sources, if any.

### Second Boundary Survey (1891 to 1894)

During the second Boundary Survey mollusks were collected by E. A. Mearns, who like T. H. Webb was medical officer to the party. Unlike Webb, MEARN'S (1907) wrote an exemplary account of his itinerary and collecting localities. This work is of value because of its detailed description of places that have been modified subsequently by agriculture and irrigation development. DALL's (1896) report on the mollusks mislocates some localities, or locates them less precisely than Mearns. In the following list the mollusks are discussed by Mearns' collecting stations, in east-west sequence. In all cases quotations describing the localities are from Mearns' account. The citation of USNM catalogue numbers indicates I have examined the specimens, the lack of such citation that I have not been able to find the specimens in USNM collections. Revised identifications of the species, and occurrence by locality, are listed in Table 1.

Mearns station 1 (NI 14-12 C-6, D-6). Fort Worth, Tarrant County, Texas. "Birds and shells were collected on the South Fork of Trinity River January 30 and 31, 1892, by Mearns and Holzner." DALL (1896: 368) recorded *Limnaea bulimoides* LEA (USNM 130185) and *Physa mexicana* PHILIPPI (USNM 130225). The latter set is labeled "Rio Grande, Ft. Worth, Texas," giving rise to the suspicion that this series is from El Paso (Mearns station 5).

Mearns station 2 (NH 14-7 B-2). Fort Clark, Kinney County, Texas. "The post is located at the head of Las Moras Creek, a wooded stream encircling it on three sides. . . ." Mearns made a few collections in 1892 and 1893, but most of the mollusks were collected in 1897-1898 after the report by DALL (1896) had been published. The following list of species was published by MEARN'S (1907: 77):

<i>Limnaea columella</i> (SAY)	(USNM 151544)
<i>Limnaea humilis</i> SAY	
<i>Physa osculans</i> HALDEMAN	(USNM 218412)
<i>Planorbis liebmanni</i> DUNKER	
<i>Planorbis tumidus</i> PFEIFFER	(USNM 218424)
<i>Planorbis triolvis</i> SAY	
<i>Planorbis bicarinatus</i> SAY	(USNM 151533)
<i>Valvata guatemalensis</i> MORELET	(USNM 151532, 218425, 218426)

*Amnicola peracuta* WALKER

*Amnicola* sp.

*Sphaerium elevatum* HALDEMAN

Table 1

Freshwater Mollusks Collected by E. A. Mearns during the Second United States and Mexican Boundary Survey.

	Mearns Localities																		
	1	2	5	8	24	25	46	58	66	67	68	73	76	77	81	91	92	219	
<i>Bakerylmnaea techella</i> (HALDEMAN, 1867)	×		×																
<i>Physa virgata</i> GOULD, 1855 a	?	×	?	×	×	×	×		×		×		×			×	×		
<i>Elliptio popeii</i> (LEA, 1857)		×																	
<i>Lampsilis anodontoides</i> (LEA, 1830)		×																	
<i>Cyrtoneias tampicoensis berlandieri</i> (LEA, 1857)		×																	
<i>Carunculina parva compressa</i> (SIMPSON, 1900)		×																	
<i>Carunculina parva mearnsi</i> (SIMPSON, 1900)		×																	
<i>Carunculina parva texasensis</i> (LEA, 1857)		×																	
<i>Megalonaias gigantea</i> (BARNES, 1823)		×																	
<i>Quadrula couchiana</i> (LEA, 1860)		×																	
<i>Anodonta imbecillis horda</i> GOULD, 1855 b		×																	
<i>Sphaerium partumeium</i> (SAY, 1822)		×																	
<i>Sphaerium striatinum</i> (LAMARCK, 1818)		×																	
<i>Pisidium compressum</i> PRIME, 1852		×		×		×	×												
<i>Cincinnatia peracuta</i> (PILSBRY & WALKER, 1889)		×																	
<i>Cochliopina riograndensis</i> (PILSBRY & FERRISS, 1906)		×																	
" <i>Amnicola</i> " sp.		×																	
<i>Fossaria obrussa</i> (SAY, 1825)		×					×												
<i>Pseudosuccinea columella</i> (SAY, 1817)		×																	
<i>Biomphalaria liebmanni</i> (DUNKER, 1850)		×																	
<i>Helisoma anceps</i> (MENKE, 1830)		×																	
<i>Planorbella trivolvis</i> (SAY, 1816)		×																	
<i>Planorbella tenuis</i> (DUNKER, 1850)			×			×	×	×		×			×	×	×			×	
" <i>Bythinella</i> " <i>palomasensis</i> PILSBRY, 1895				×															
<i>Anodonta dejecta</i> LEWIS, 1875						×													
<i>Sphaerium triangulare</i> (SAY, 1829)						×													
<i>Anodonta californiensis</i> LEA, 1852							×			×	×				×			×	
<i>Physa humerosa</i> GOULD, 1855 a													×					×	
<i>Biomphalaria gracilentia</i> (GOULD, 1855 a)																×			
<i>Tryonia protea</i> (GOULD, 1855 a)																		×	

*Sphaerium solidulum* PRIME (USNM 151 541,  
216 217, 216 218, 216 219)

*Pisidium compressum* PRIME

*Lampsilis anodontoides* LEA

*Lampsilis texasensis* LEA (USNM 151 536, 151 540)

*Lampsilis texasensis compressus* SIMPSON  
(USNM 151 539, 152 059)

*Lampsilis berlandieri* LEA (USNM 151 548)

*Lampsilis mearnsi* SIMPSON (USNM 151 549,  
308 846)

*Anodonta imbecillis* SAY

*Unio popeii* LEA (USNM 308 943)

*Quadrula undulata* BARNES

*Quadrula couchiana* LEA (USNM 308 855)

From the earlier collections by Mearns, 1892 - 1893,  
DALL (1896: 368 - 371) recorded *Physa mexicana* PHIL-

IPPI from Fort Clark (USNM 130 226), *Planorbis tumidus* PFEIFFER from Las Moras Creek (USNM 130 228), *Unio couchianus* LEA without locality (USNM 130 207, 152 058), *Unio undulatus* BARNES from Kinney County, and *Unio popeii* from Kinney County (USNM 130 175, 151 538). From the description of his collecting by MEARN'S (1907) I suppose that all of these specimens came from nearby Fort Clark, in spite of the discrepant published data. C. T. SIMPSON (1900) described *Lampsilis mearnsi* from Mearns' collections around Fort Clark.

Two labels with a series of paratypes of *Lampsilis mearnsi* (USNM 151 549) provide discrepant locality data. One label says "Ft. Clark, Texas," the other "Elm Cr., 24 mi. S. Ft. Clark, Texas." The label of USNM 308 846 says "from pool, 20 mi. S. of Ft. Clark, Texas," with a note on the back quoting Mearns: "These are

topotypes, collected at the same time and place as the types."

The specimens of *Cochliopina riograndensis* (PILSBRY & FERRISS) recorded by TAYLOR (1966b: 177) from Kinney County, Texas, without more precise data probably come from Mearns' collection at Fort Clark.

Mearns station 5 (NH 13-1 D-2). El Paso, El Paso County, Texas. Collections were made by Mearns in February, March, and November, 1892, and June, 1893. MEARN'S (1907: 80) noted that "Fresh-water mollusks are numerous in the Rio Grande." DALL (1896: 368-369) recorded *Limnaea bulimoides* LEA (USNM 130 186, 130 235) and *Planorbis tumidus* PFEIFFER (USNM 130 239) from the Rio Grande "near El Paso." BAKER (1945, plt. 98, fig. 25; plt. 99, figs. 9, 10) illustrated some of the "*Planorbis tumidus*" as *Helisoma tenue sinuosum* (BONNET). I suspect the record by BAKER (1911: 216) of *Galba bulimoides techella* from the Rio Grande, near El Paso, is based on Mearns' specimens.

Mearns station 8 (NH 13-1 D-7). "Palomas Lakes, Mimbres Valley, Chihuahua, Mexico. One mile south of Monument No. 21." Collections were made from April 7 to 15, 1892. DALL (1896: 368-370) recorded *Physa mexicana* PHILIPPI (USNM 130 183), *Bythinella palomasensis* PILSBRY (USNM 130 016) and *Pisidium compressum* PRIME (specimens not found). PILSBRY (1895) described *B. palomasensis* from these specimens, the label of which gives the locality as "Mimbres valley near boundary monument 19." Monument 21 is in the W $\frac{1}{2}$  sec. 18, T. 29 S., R. 7 W., and monument 19 in the E $\frac{1}{2}$  of sec. 14 of the same township, 4.6 miles to the east. The types of *B. palomasensis* were not alive when collected, for the shells are white and bleached. They are perhaps fossil, or at least stream-drifted.

Mearns station 24 (NH 12-3 B-5). Hall's Ranch, Guadalupe Canyon, Sonora. "Camp was made at Monument No. 73, in the canyon." The locality is 2100 feet west, 900 feet south of the northeast corner sec. 21, T. 24 S., R. 32 E., Cochise County, Arizona. Mearns camped here in July and August, 1892; and August and October, 1893. DALL (1896: 368) recorded *Physa mexicana* PHILIPPI (USNM 130 182) from Guadalupe Canyon, New Mexico.

Mearns station 25 (NH 12-3 B-6). San Bernardino Ranch, Cochise County, Arizona. "Camp was made at Monument No. 77, in a mesquite flat between the San Bernardino Springs and the neighboring San Bernardino River." Mearns' collections seemingly came from the Rio San Bernardino on both sides of the boundary. The river crosses the boundary line in the San Bernardino grant, in what would be the NW $\frac{1}{4}$  sec. 23, T. 24 S., R. 30 E., Cochise County, Arizona. Mearns camped here in July and September, 1892; and in August and October, 1893.

DALL (1896) recorded several species from "San Bernardino River," variously quoted by him in Arizona, New Mexico, and northern Mexico: *Physa mexicana* PHILIPPI (USNM 130 219), *Planorbis tumidus* PFEIFFER (USNM 130 230, 130 233), *Sphaerium solidulum* PRIME (USNM 130 236), *Pisidium compressum* PRIME (USNM 130 241), and *Anodonta dejecta* LEWIS (USNM 130 208).

Victor Sterki applied the manuscript name *Sphaerium eminens* to this collection of *Sphaerium*. No formal description has been published but BROOKS & HERRINGTON (1944: 95) cited *S. eminens* in the synonymy of *S. striatinum* LAMARCK. In my opinion these specimens are *S. triangulare* (SAY). SIMPSON (1893) described *Anodonta mearnsiana* (a synonym of *A. dejecta*) from this collection.

The *Physa* (USNM 130 219) is identified as *Physa virgata* in a comprehensive sense, but the series is not typical and might come from an unusual habitat, or represent another species. Some of the smaller specimens are usual *P. virgata* in shape, but most are short-spined with an expanded body whorl.

Mearns station 46 (NI 12-11 A-4). Tucson, Pima County, Arizona. Mearns collected both living and stream-drifted specimens in the Santa Cruz River near Tucson, in October, November, and December, 1893. From the river drift "near Tucson" DALL (1896: 368-369) recorded *Limnaea desidiosa* SAY and *Aplexa hypnorum* LINNAEUS, and from the Santa Cruz River near Tucson, DALL (1896: 368-369, 373) listed *Physa mexicana* PHILIPPI (USNM 130 220), *Planorbis tumidus* PFEIFFER (USNM 130 237), and *Anodonta dejecta* LEWIS (USNM 130 172, "Tucson," USNM 130 180, "Santa Cruz River, near Tucson"). STEARNS (1901: 289) suggested the "*Aplexa hypnorum*" might prove to be one of the Mexican species now classified in *Physa* (*Stenophysa*), but I consider the single specimen (USNM 130 188) is only an elongate *Physa virgata*. Some of the "*Planorbis tumidus*" (USNM 130 237) were illustrated by BAKER (1945, plt. 98, figs. 9 - 13; plt. 99, figs. 4 - 8) as *Helisoma tenue sinuosum* (BONNET). The record of *Limnaea desidiosa* was assigned by BAKER (1911: 272) to *Galba obrussa* (SAY). A lot of *Pisidium compressum* PRIME (USNM 130 243) was not mentioned by DALL (1896).

Mearns station 58 (NH 12-1 D 5). "Rancho de Agua Dulce, Sonoyta River, Sonora, Mexico. This place is about 6.4 kilometers (4 miles) southwest of Monument No. 173." Mearns collected here in January and February, 1894. DALL (1896: 369) recorded *Planorbis tumidus* PFEIFFER from "Sonoyta River, northern Mexico." The specimens are USNM 130 229, one of which was illustrated by BAKER (1945, plt. 98, fig. 14) as *Helisoma tenue sinuosum* (BONNET), from "Sonoyta" Creek, Sonora.

Mearns station 66 (NI 11-12 D-2). Gila River at Gila City (now Dome), Yuma County, Arizona. "Along the Gila River are numerous sloughs, bordered with cat-tail, tule, cane, sedge, and rush." A series of *Physa virgata* GOULD (USNM 187481) collected by Mearns during March 1 to 5, 1894, was not mentioned by DALL (1896).

Mearns station 67 (NI 11-12 C-3 A). Yuma, Yuma County, Arizona. "This station is on the left (east) bank of the Colorado River, at the mouth of the Gila," where Mearns collected in March and April, 1894. DALL (1896: 369) recorded *Planorbis tumidus* PFEIFFER (USNM 130232, 130234).

Mearns station 68 (NI 11-12 B-4). Monument No. 204. "This camp was beside a laguna of the Colorado River, at the east edge of the bottom land," sec. 12, T. 11 S., R. 25 W., Yuma County, Arizona. Mearns collected here during March, 1894. DALL (1896: 373) recorded *Anodonta dejecta* LEWIS from "Colorado River, near the Mexican boundary." The specimens (USNM 130171) are labeled monument 204. A series of *Physa virgata* GOULD (USNM 130224) from this collection was overlooked by DALL (1896).

Mearns station 73 (NH 11-3 D-4). "Left (east) bank of the Colorado River, opposite the mouth of Hardy River, Sonora, Mexico." Mearns collected mollusks here during March, 1894. DALL (1896: 373) recorded *Anodonta dejecta* LEWIS from "mouth of Colorado River" (USNM 128801).

Mearns station 76 (NI 11-12 C-5). Seven Wells, Baja California. "This station is 8 kilometers (5 miles) south of Monument No. 213." Mearns collected mollusks here during April, 1894. Seven Wells was a former watering place on the wagon road between Yuma, Arizona, and San Diego, California. It is shown on the U. S. Geological Survey "Reconnaissance map of the Salton Sink, California" (1908), scale 1 : 500 000. DALL (1896: 368-369) recorded *Planorbis tumidus* PFEIFFER (USNM 130238) and *Physa mexicana* PHILIPPI (USNM 130217, subfossil?) from Seven Wells, Arizona.

Mearns station 77 (NI 11-12 C-5). Gardners Laguna, Baja California. "Station about 10 kilometers (6 miles) south of Monument No. 216." Mearns collected here during April, 1894. This was evidently one of a series of ponds and sloughs along the course of the Alamo River at that time. DALL (1896: 369) recorded *Planorbis tumidus* PFEIFFER (USNM 128952).

Mearns station 81 (NI 11-12 C-7 or D-7). Laguna Station, Imperial County, California. "Station about 11 kilometers (7 miles) north of Monument No. 224," where Mearns camped May 3 to 6, 1894. This locality was a

station on New River, about sec. 25, T. 16 S., R. 12 E. DALL (1896: 369, 373) recorded *Planorbis tumidus* PFEIFFER (specimens not found), *Anodonta dejecta* LEWIS (USNM 128812) and *A. californiensis* LEA (USNM 128817).

Mearns station 91 (NI 11-11 C-2). "Thomas Cameron's Ranch, San Diego County, California, 13 kilometers (8 miles) nearly north of Monument No. 240." Mearns collected here June 21 to 23, 1894. Cameron Valley is traversed by La Posta Creek in secs. 9, 10, and 16, T. 17 S., R. 5 E., evidently the source of the specimens (USNM 130218) that DALL (1896: 368) recorded as *Physa mexicana* PHILIPPI.

Mearns station 92 (NI 11-11 D-2). "Campbell's Ranch, at Laguna Mountains (Coast Range), San Diego County, California, 31 kilometers (19 miles) north of Monument No. 240." Mearns collected here June 9 to 21, 1894. DALL (1896: 368-369) recorded as from "Laguna, 20 miles north of Campo" *Physa mexicana* PHILIPPI (USNM 130223) and *Planorbis liebmanni* DUNKER (specimens not found). The locality is evidently either Big Laguna Lake or Little Laguna Lake, both in sec. 10, T. 15 S., R. 5 E.

Monument 219 (NI 11-12 C-6B). This monument on the international boundary is in sec. 15, T. 17 S., R. 15 E., Imperial County, California, about 3½ miles east of Cal-exico. Mearns assigned no station number. The specimens are all fossils from the surface of the desert, and were recorded by DALL (1896: 369, 373, 376) as *Planorbis tumidus* PFEIFFER (specimens not found), *Anodonta californiensis* LEA (USNM 128802), *Physa humerosa* GOULD (specimens not surely found), and *Amnicola protea* GOULD. The series of *Physa* from this locality might be USNM 130184, a set of subfossil *P. humerosa* labeled as collected by Dr. Mearns but without locality data.

A series of subfossil specimens of *Physa humerosa* GOULD (USNM 130450) is labeled as coming from "Salt Creek, W. side of Colorado Desert," collected by Mearns. This collection is not from any of MEARNS' (1907) numbered stations.

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# New Records of Nudibranchia

(Gastropoda : Opisthobranchia : Nudibranchia)

## from the Central and West-Central Pacific

### with a Description of a New Species

BY

DAVID K. YOUNG

Department of Zoology  
University of Hawaii, Honolulu, Hawaii 96822<sup>1,2</sup>

(18 Text figures)

#### INTRODUCTION

INFORMATION ON THE nudibranchiate opisthobranchs of the Central and West-Central Pacific consists chiefly of morphological studies on preserved specimens collected during exploratory expeditions to the Pacific Islands. A recent example is the taxonomic study of MARCUS (1965) on Micronesian opisthobranchs in which 28 species of nudibranchs are identified, 7 of which are new.

The purpose of this paper is to present new records and biological notes of nudibranchs collected from Palmyra Atoll, Johnston Island, and Eniwetok Atoll. Palmyra Atoll, the northernmost of the Line Islands, is located at 5° 51' N and 162° 04' W. Johnston Island, which is located at 16° 15' N and 169° 30' W, is unusual in that it has a marginal reef only at one side and that it comprises the only land mass in the triangular area formed by the Hawaiian Islands 450 miles to the northeast, the Line Islands 700 miles to the southeast and the Marshall Islands 1300 miles to the west. Eniwetok Atoll, one of the westernmost of the Marshall Islands, is located at 11° 30' N and 162° 15' E.

Nudibranchs have not previously been reported from Palmyra Atoll and Johnston Island, whereas MARCUS & BURCH (1965) report 8 species of nudibranchs from Eniwetok Atoll, 2 of which are new. One specimen of *Hexabranchius marginatus* (QUOY & GAIMARD, 1832), identified by MARCUS (1965) from a 1946 collection of J. P. E. Morrison, in addition to these 8 species, makes a total of 9 nudibranchs previously reported from Eniwetok.

#### ACKNOWLEDGMENTS

Nudibranchs were collected from Eniwetok Atoll between June 21 and July 9, 1965 under the auspices of the AEC Eniwetok Marine Biological Laboratory and the director, Dr. Robert W. Hiatt (University of Hawaii), to whom the author gives grateful acknowledgment for financial support. Specimens from Palmyra Atoll and Johnston Island were collected in June, 1962 and August, 1965 by the Hawaii Institute of Marine Biology and were given to the author by Dr. E. Alison Kay (University of Hawaii) and Mr. William van Heukelem (University of Hawaii). Special thanks are due Dr. E. Alison Kay for her interest and aid in all aspects of this study. Appreciation is also due Dr. Gerald J. Bakus (University of Southern California) for his identification of the sponges in this study. The author appreciates the comments and criticisms of the manuscript by Dr. Melbourne R. Carriker, Dr. Victor A. Zullo, Dr. Barry A. Wade and Dr. Thomas J. M. Schopf (all of the Systematics-Ecology Program, Marine Biological Laboratory).

<sup>1</sup> Contribution No. 272, Hawaii Institute of Marine Biology, Honolulu, Hawaii. Work supported by the AEC Eniwetok Marine Biological Laboratory and a Marine Science Graduate Research Fellowship from the Bureau of Commercial Fisheries. Based on a doctoral dissertation submitted to the Graduate School, University of Hawaii, Honolulu, Hawaii.

<sup>2</sup> Present address: Systematics-Ecology Program, Marine Biological Laboratory, Woods Hole, Massachusetts 02543

## COLLECTIONS AND METHODS

Except for one specimen collected from Iguir Island, Eniwetok Atoll, two specimens from Palmyra Atoll and one specimen from Johnston Island, the nudibranchs discussed in this paper are from three locations on Eniwetok Atoll: (1) a subtidal flat at the northern lagoonward side of Chinimi Island, (2) a tidepool on the northern lagoonward side of Eniwetok Island, and (3) the quarry on the northern seaward reef of Eniwetok Island. These three sites represent a type of shallow water environment relatively rare on Eniwetok Atoll: rock areas comparatively free of sand and carbonate sediment and with a free exchange of water at all stages of the tide.

Collections were made from the intertidal zone to a depth of 5 meters. Species of Doridacea from Hawaii referred to in this paper were collected from the islands of Oahu and Kauai between 1962 and 1966. Descriptions, figures and ecological notes will be given for these and other species in a paper by KAY & YOUNG (in preparation).

Descriptions, measurements and drawings of external morphological features were made from live specimens. Observations of feeding, when possible, were made from animals held in laboratory aquaria. Internal anatomical examination was performed on specimens relaxed by refrigeration, fixed in 5% formalin and stored in 70% ethyl alcohol. Animals are described and figured where these data are not adequately provided in the literature.

## SPECIES

## DORIDACEA

## DORIDIDAE

*Doriopsis viridis* PEASE, 1861

(Text figures 1 to 3)

*Doriopsis viridis* PEASE, 1861: 244 - 245; PEASE, 1871: 301, plt. 19, figs. 1 a, 1 b, 1 c

*Guyonia viridis* (PEASE), RISBEC, 1928 (in part): 106 (*variété verte* not *variété bleu*)

*Doriopsis viridis* (PEASE), RISBEC, 1953 (in part): 45 (*variété verte* not *variété bleu*)

**Description:** *Doriopsis viridis* has an oblong body that is flattened dorso-ventrally (Figure 1). No specimens were found greater than 8 mm in length and 3 mm in width. The mantle, foot, rhinophores and branchiae are olive green to bronze green. The mantle, which flares around the foot, is firm and has small spiculate pustules resembling "granules" over the dorsum. Along the mid-dorsum, elongate epidermal spicules are arranged diagonally in

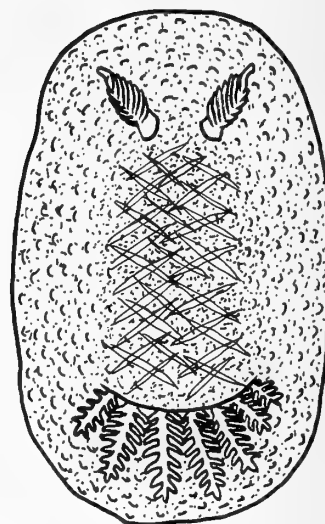


Figure 1

*Doriopsis viridis*  
Dorsal view of adult specimen

approximately alternate series. The 7 to 8 branchiae are simply pinnate and retractile into the transversely positioned, crescent shaped branchial sheath at the posterior end of the mantle. The rhinophores are rod-like with 6 to 9-lamellae and are retractile into separate sheaths.

The radular formula of 2 specimens, 6 and 8 mm long, is 26-30 x 24-26 · 0 · 24-26 (Figure 2). The radular teeth are hamate, non-denticulate and range in size from 46 $\mu$  to a maximal length of 119 $\mu$  in an 8 mm specimen. The largest teeth are centrally positioned within each row. No jaws are present. Ducts in the female portion of the reproductive system (Figure 3, ud, v) are parallel in arrangement. The spermatocyst (sc) is ovate-oblong and smaller than the spherical spermatheca (st).

**Habits:** Four specimens were collected on the lagoon side of the northern end of Chinimi Island, Eniwetok Atoll. Specimens were found eating the orange sponge, *Prianos phlox* DE LAUBENFELS, 1954, which occurred in abundance on the undersides of rocks at the collecting site. Examination of feces revealed spicules of the same sponge and laboratory feeding tests suggested that specimens of *Doriopsis viridis* fed exclusively on *P. phlox*.

A 7 mm specimen produced a light yellow, ribbon-like egg mass, 60 mm long and 1.5 mm wide, with 3 whorls. The egg mass contained approximately 72 ova per mm<sup>2</sup>. Each ovum was enclosed by a capsule 150 $\mu$  to 162 $\mu$  in diameter. The larvae hatch as free swimming veligers.

**Remarks:** Two color "varieties" of *Doriopsis viridis* are

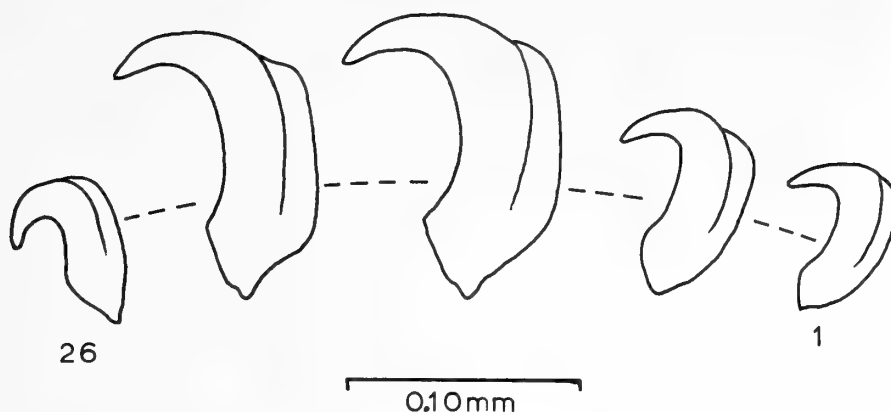


Figure 2

*Doriopsis viridis*

Lateral view of the left half row of radular teeth

1 = innermost lateral

26 = outermost lateral

proposed (RISBEC, 1928, 1953) and *Doriopsis pecten* COLLINGWOOD, 1881, the blue variety, is synonymized with *D. viridis* PEASE, 1861, the green variety (ALLAN, 1947; BABA & HAMATANI, 1961). The two species are similar in many external and internal morphological characters, but when specimens of similar size are compared, specimens of *D. viridis* have larger eggs, larger radular teeth and fewer teeth per radular row than specimens of *D. pecten*. The species are further distinguished by different feeding habits (see below).

Specimens of *Doriopsis viridis* are reported from Tahiti (PEASE, 1861, 1871) and New Caledonia (RISBEC, 1928, 1953).

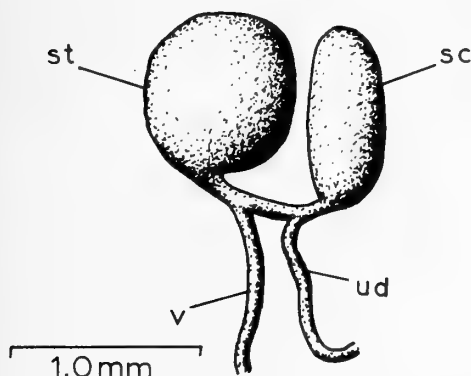


Figure 3

*Doriopsis viridis*

Lateral view of the female duct system

sc = spermatocyst

st = spermatheca

ud = uterine duct

v = vaginal duct

*Doriopsis pecten* (COLLINGWOOD, 1881)

**Description:** The animal is figured and described by COLLINGWOOD (1881), ALLAN (1947) and BABA & HAMATANI (1961). The radular formula is given by BABA & HAMATANI (1961). HAMATANI (1961) provides a photograph of specimens in association with encrusting blue sponge colonies and descriptions of eggs and veliger larvae. Synonymies are given and additional features of the external and internal morphology of *Doriopsis pecten* are described and figured by KAY & YOUNG (in preparation). **Habits:** Four specimens (6 mm to 11 mm long) were collected at Eniwetok Atoll. One specimen was found in the quarry on Eniwetok Island in 2 m depth and the other specimens were collected from 0.5 m depth on the northern lagoonward side of Chinimi Island. They were seen feeding on the blue sponge, *Terpios aploos* DE LAUBENFELS, 1954, which was fairly abundant under rocks and in crevices in dead coral at both collecting sites. Spicules of *T. aploos* were found in the feces and gut contents of freshly collected specimens. Specimens of *Doriopsis pecten* in Hawaiian waters (unpublished data) were also found to specifically eat *T. aploos*.

**Remarks:** The occurrence of mutually exclusive feeding habits is confirmatory ecologic evidence that *Doriopsis pecten* and *D. viridis* are distinct species and that the blue coloration of *D. pecten* is specifically diagnostic.

Specimens of *Doriopsis pecten* are reported from Taiwan (COLLINGWOOD, 1881), Japan (BABA & HAMATANI, 1961), New South Wales (ALLAN, 1947), and are found in Hawaii (KAY & YOUNG, in preparation) in addition to New Caledonia (RISBEC, 1928, 1953), where they co-occur with specimens of *D. viridis*.

*Hypselodoris tryoni* (GARRETT, 1873)

(Text figures 4 to 7)

*Goniodoris tryoni* GARRETT, 1873: 232; plt. 4*Chromodoris tryoni* (GARRETT), BERGH, 1877: 490; BERGH, 1884: 69

**Description:** *Hypselodoris tryoni* has an elongate smooth body up to 60 mm in length and 18 mm in width (Figure 4). The convex mantle is expanded anteriorly as a hood,

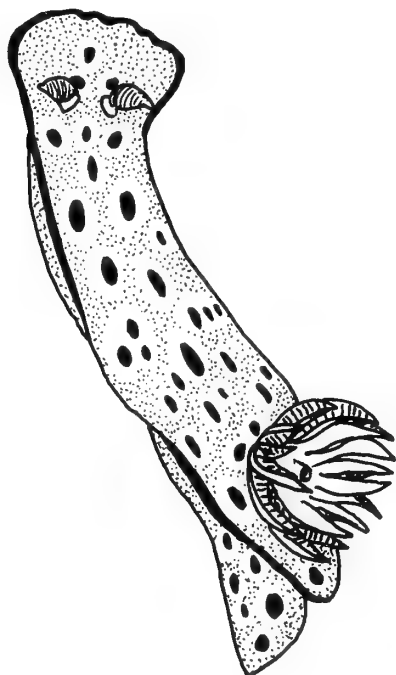


Figure 4

*Hypselodoris tryoni*  
Dorsal view of adult specimen

rounded posteriorly and held above the foot. The foot is elongate, tapered and projected posteriorly beyond the mantle edge. The background color of the mantle is cream or light brown. The mantle is bordered and spotted with purple maculae each of which is surrounded by a white areola in turn encircled by a pale fawn ring. The foot is white, margined with lilac and covered with spots similar to those on the mantle. The rhinophores are rod-like, elongate, finely lamellate, retractile into widely separated sheaths, and brown with a white medial streak anteriorly. The 14 to 16 branchial plumes, which encircle the posteriorly positioned anus, increase in arborization and decrease in size posteriorly. They are erect, vibratory and white with red-brown margins. The rhachides are quadrangular in cross section and retractile into a common cavity.

The radular formula of a 60 mm specimen is 94 x 58-0-58 (Figure 5). The innermost radular tooth is simply

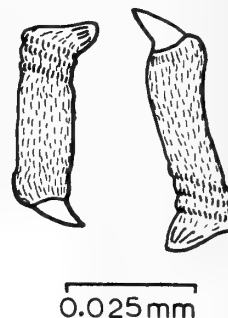


Figure 6

*Hypselodoris tryoni*  
Elements of the buccal armature

bicuspid and 50  $\mu$  long. Within each row, denticulation increases laterally to a maximum of six outer denticles and tooth length increases centrally to 83  $\mu$ . The buccal arma-

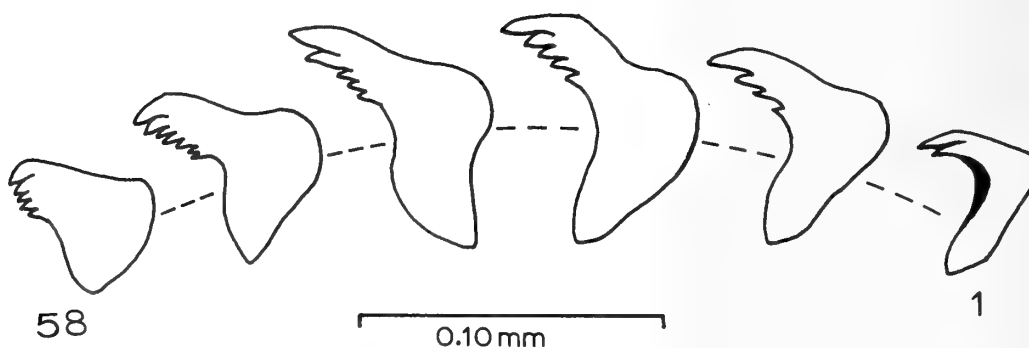


Figure 5

*Hypselodoris tryoni*  
Lateral view of the left half row of radular teeth  
1 = innermost lateral      58 = outermost lateral

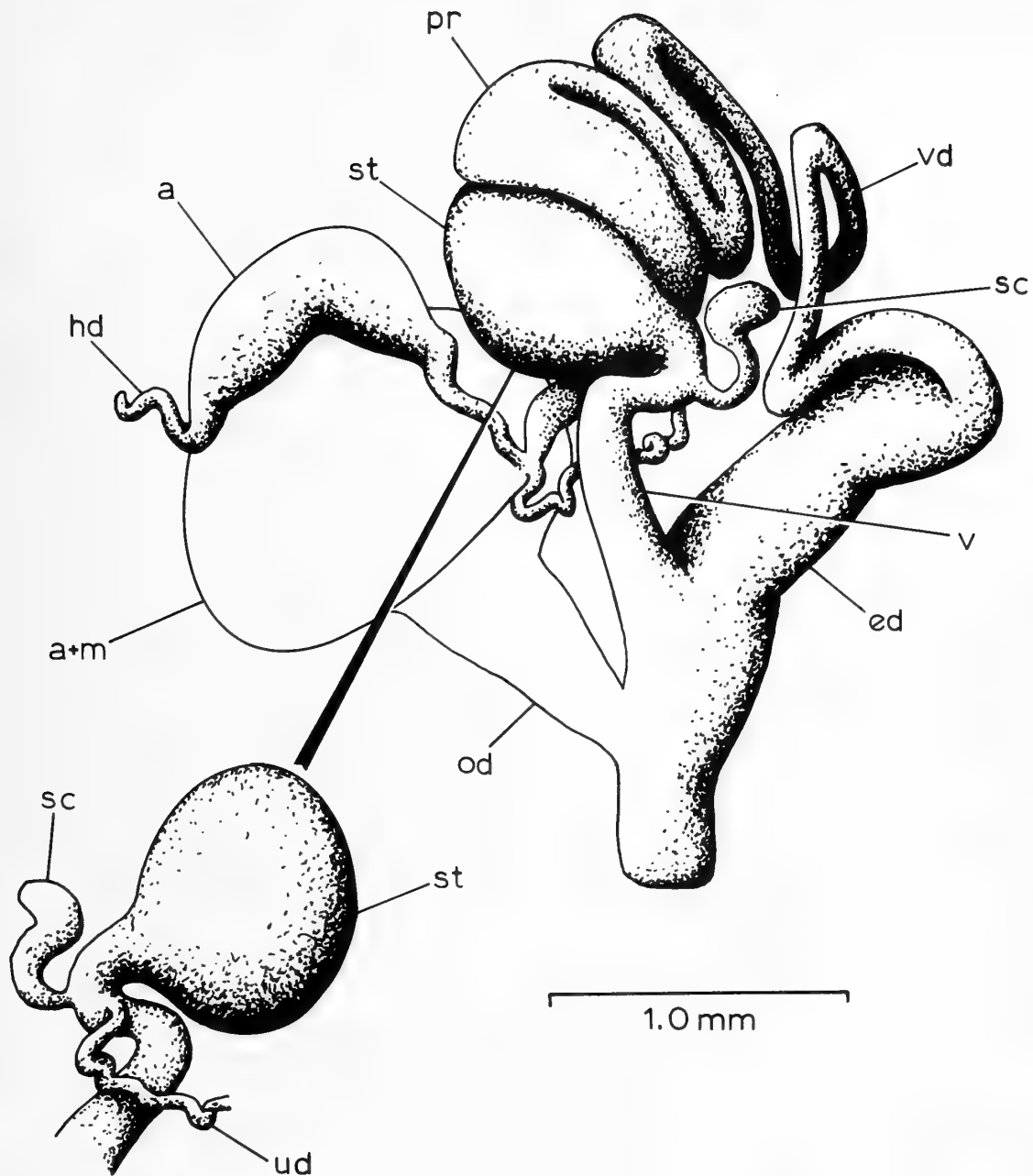


Figure 7

*Hypselodoris tryoni*

Lateral view of the genital mass with an offset of a medial view of the female duct system

- |                       |                                |                  |                     |                   |
|-----------------------|--------------------------------|------------------|---------------------|-------------------|
| a = ampulla           | a+m = albumin and mucous gland | od = oviduct     | pr = prostate gland | sc = spermatocyst |
| ed = ejaculatory duct | hd = hermaphroditic duct       | st = spermatheca | ud = uterine duct   | v = vaginal duct  |
|                       | vd = vas deferens              |                  |                     |                   |

ture, which ranges in length from 45 to 50 $\mu$ , has singly hooked tips and long sculptured bases (Figure 6).

A common orifice (Figure 7) is shared by the ejaculatory duct (ed), vaginal duct (v) and oviduct (od). No cirral hooks line the ejaculatory duct. The elongate prostate gland (pr) partially envelops the spermatheca (st). The vaginal duct is short and non-convolute and passes directly into the spherical spermatheca. A short duct passes from the spermathecal end of the vaginal duct into the small pyriform spermatocyst (sc). A long, tightly convolute uterine duct (ud) joins the junction of the prostatic and ampullary ducts at the albumin and mucous gland (a+m).

**Habits:** Two specimens were found on dead coral in the lagoon of Palmyra Atoll. The structure and arrangement of the digestive system indicates that this species is a rasping sponge-feeder. The food was not determined.

**Remarks:** On the basis of specimens collected in Zanzibar, ELIOT (1904) suggested that the dorid *Chromodoris aureopurpurea* COLLINGWOOD, 1881, from the China coast is a variety of *Hypselodoris tryoni*. However, *C. aureopurpurea* has characters which are sufficiently distinctive so that this species should be regarded separately from *H. tryoni* as originally suggested by COLLINGWOOD.

Specimens of *Hypselodoris tryoni* are reported from the Society Islands (GARRETT, 1873) and the Philippines (BERGH, 1877).

*Hypselodoris kayae* YOUNG, new species

(Text figures 8 to 11)

**Description:** *Hypselodoris kayae* has a smooth, elongate body with maximal dimensions of 10 mm length and 3 mm width (Figure 8). The mantle is convex and held above

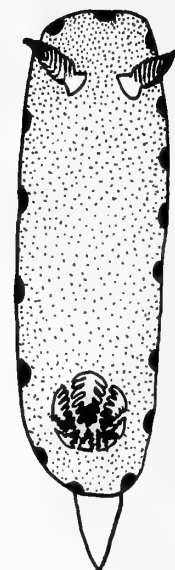


Figure 8

*Hypselodoris kayae*  
Dorsal view of adult specimen

the foot. The elongate, white foot tapers and extends posteriorly to the mantle, which is light lilac, edged with irregularly spaced rose red spots. The rhinophores are rod-like, white with rose red tips and retractile into closely spaced sheaths; there are 8 to 9 lamellae. The 7 branchiae are in a circlet about the posterior mid-dorsal anus; they are simply pinnate, white, tipped with rose red, smaller posteriorly and retractile into a common cavity.

The radular formula of a 10 mm specimen is 28 x 21-0-21 (Figure 9). The innermost radular tooth, 25 $\mu$  long, is bi-

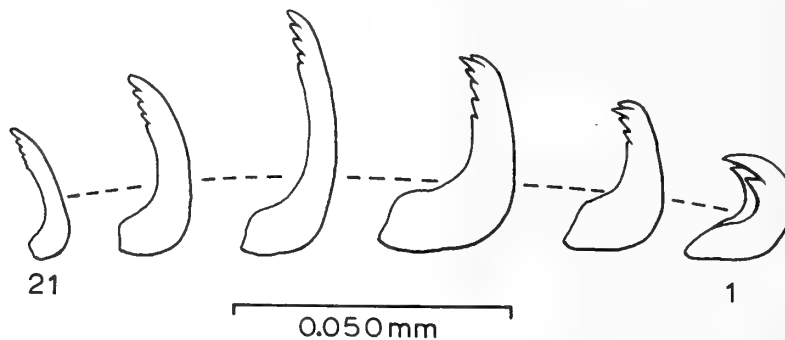


Figure 9

*Hypselodoris kayae*

Lateral view of the left half row of radular teeth

1 = innermost lateral

21 = outermost lateral

cuspid with a single outer denticle. The teeth increase in denticulation and size towards the center within each row to a maximal number of 4 outer denticles and a length of  $46\mu$ . The buccal armature consists of small bifid hooks, 12 to  $16\mu$  long, with broad sculptured bases (Figure 10).



Figure 10

*Hypselodoris kayae*  
Elements of the buccal armature

The ejaculatory duct (ed), vaginal duct (v) and oviduct (od) have separate, external orifices (Figure 11).

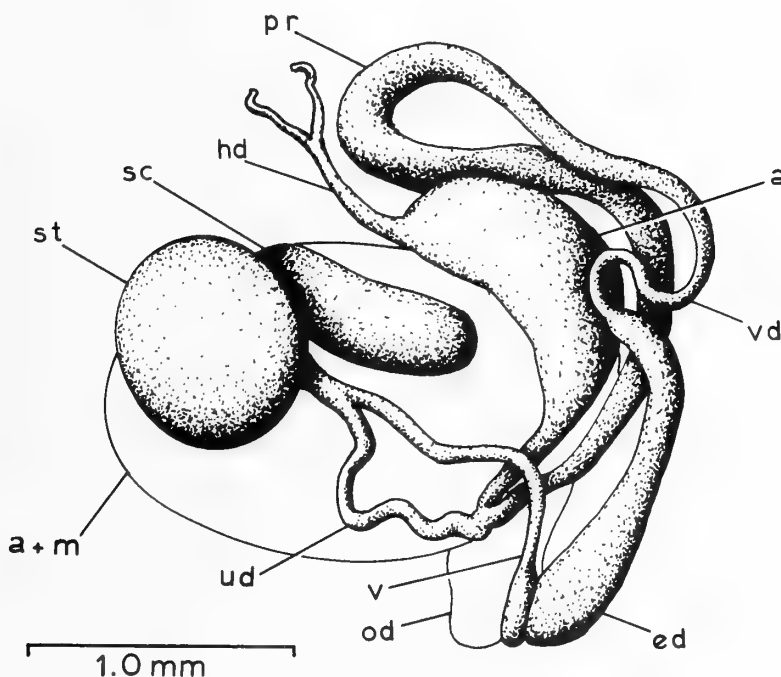


Figure 11

*Hypselodoris kayae*

Lateral view of the genital mass

a = ampulla	a+m = albumin and mucous gland	od = oviduct	pr = prostate gland	sc = spermatocyst
ed = ejaculatory duct	hd = hermaphroditic duct	st = spermatheca	ud = uterine duct	v = vaginal duct
	vd = vas deferens			

No cirral hooks line the ejaculatory duct. The ejaculatory duct, vas deferens (vd) and prostate gland (pr) are loosely convolute and merge imperceptibly. The vaginal duct joins the uterine duct (ud) and forms a common vaginal-uterine duct which in turn leads to the junction of the spermatheca (st) and spermatocyst (sc). The oblong spermatocyst connects directly with the spherical spermatheca. The long, loosely convolute uterine duct passes from the vaginal duct and merges with the ampullary and prostatic ducts at the albumin and mucous gland (a+m).

**Habits:** Two specimens, 6 mm and 10 mm long, were collected from underneath a rock at 0.5 m depth on the northern lagoonward side of Chinimi Island, Eniwetok Atoll. They were found eating a rose-red sponge, *Aplysilla glacialis* DE LAUBENFELS, 1951, which was a common encrusting sponge upon which the dorids were inconspicuous. Spicules of this sponge were recovered from the feces of both specimens. The specimens also ate *A. glacialis* in laboratory aquaria.

An egg mass produced by the 10 mm specimen was a doubly whorled white ribbon, 15 mm long and 1.7 mm wide. The ova,  $75\mu$  in diameter, were individually enclosed

in capsules,  $100\mu$  in diameter. There were approximately 320 ova per  $\text{mm}^2$  of egg mass. The larvae hatch as free swimming veligers.

**Type locality:** Lagoon, north side of Chinimi Island, Eniwetok Atoll, Marshall Islands,  $11^\circ 30' \text{ N. } 162^\circ 15' \text{ E.}$

**Type material:** The holotype and the paratype (slide of radular teeth) are deposited in the Bishop Museum, Honolulu, Hawaii, where they are registered as No. 8918. The species is named for Dr. E. Alison Kay.

**Diagnosis:** *Hypselodoris kayae* is easily distinguished from other species of *Hypselodoris* by the light lilac mantle edged with rose red spots, the white foot, and the white rhinophores and branchiae tipped with rose red.

**Remarks:** Following ODHNER (1957) this new species is placed in the genus *Hypselodoris* STIMPSON, 1855 on the basis of the predominantly bicuspidate condition of the radular teeth. Further characters shared by *H. kayae*, *H. tryoni* and 5 species of *Hypselodoris* from Hawaii (KAY & YOUNG, in preparation) are the broad, sculptured bases of the buccal armature and the united condition of the uterine and vaginal ducts at the spermatheca.

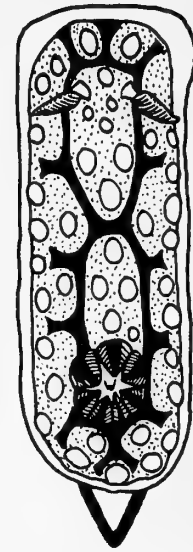


Figure 12

*Chromodoris geometrica*  
Dorsal view of adult specimen

*Chromodoris geometrica* RISBEC, 1928

(Text figures 12 to 15)

*Chromodoris geometrica* RISBEC, 1928: 148 - 151, fig. 41, plt. VI, 10;  
RISBEC, 1953: 70; figs. 31, 32

*Glossodoris geometrica* (RISBEC), ALLAN, 1947: 441; fig. 14, plt. 41

**Description:** The single specimen of *Chromodoris geometrica* collected has an oblong body, 22 mm long and 8 mm wide (Figure 12). The mantle flares about the foot, expands anteriorly as a hood and narrows posteriorly as a rounded projection. The foot broadens anteriorly into two lateral projections and tapers posteriorly beyond the

margin of the mantle which is white and fluted at the edge. Rays of purple radiate peripherally from two medial, parallel, purple bands, which in turn join anteriorly to the rhinophores, posteriorly to the branchiae and centrally at mid-body length. Enclosed by the purple reticulations are white pustules upon a light yellow background. The foot is white ventrally, light yellow dorsally and bordered with a purple margin. The rhinophores are fusiform, elongate, finely lamellate and retractile into closely spaced sheaths. The peduncles are white and the lamellae are yellow. The

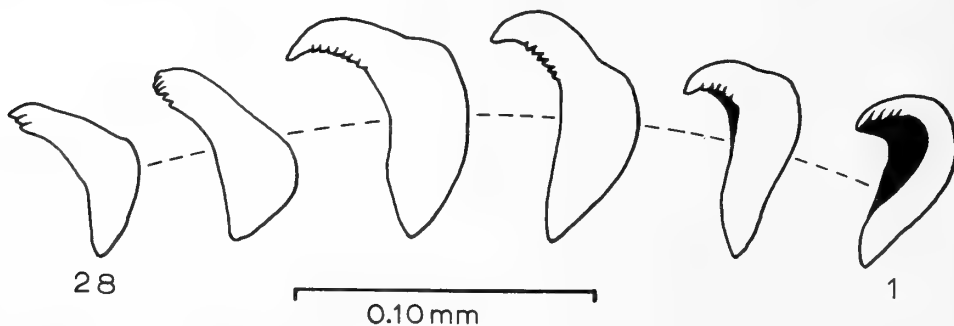


Figure 13

*Chromodoris geometrica*  
Lateral view of the left half row of radular teeth  
1 = innermost lateral      28 = outermost lateral

7 branchiae are simply pinnate with yellow rachides and transparently white pinnae; they form a circlet about the anus and decrease in size posteriorly. The rachides are quadrangular in cross section and retractile into a common cavity, but they are not vibratile as in *Hypselodoris tryoni*.

The radular formula of a 22 mm specimen is  $43 \times 28.0:28$  (Figure 13). The radular teeth are unicuspid with 2 to 9 outer denticles and range from  $53\mu$  to  $79\mu$  in length. Length and denticulation of the teeth increase centrally within each row. The outermost teeth are denticulate only at their tips. The buccal armature consists of simple bifid hooks,  $32\mu$  to  $39\mu$  long, with smooth bases (Figure 14).

The ejaculatory duct (ed), vaginal duct (v) and oviduct (od) have separate external openings (Figure 15). There are no cirral hooks in the ejaculatory duct. The prostate gland (pr) is long and tightly convoluted. The vaginal duct merges in a common duct with the uterine and spermatocystic duct which in turn passes into the

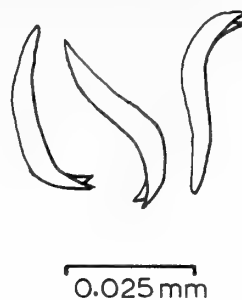


Figure 14

*Chromodoris geometrica*  
Elements of the buccal armature

spherical spermatheca (st). The spermatocyst (sc) is pyriform and approximately half the size of the spermatheca.

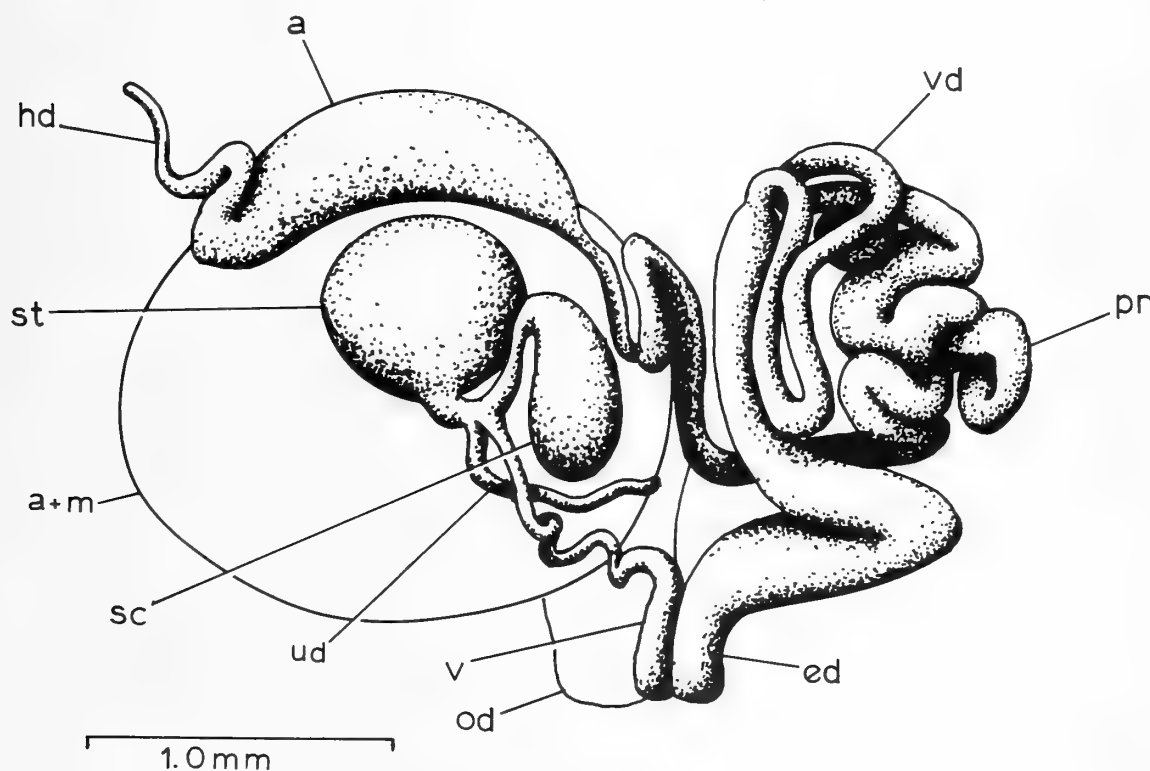


Figure 15

*Chromodoris geometrica*

Lateral view of the genital mass

a = ampulla	a+m = albumin and mucous gland	od = oviduct	pr = prostate gland	sc = spermatocyst
ed = ejaculatory duct	hd = hermaphroditic duct	st = spermatheca	ud = uterine duct	v = vaginal duct
	vd = vasa deferens			

The uterine duct (ud) enters the albumin and mucous gland (a+m) separately from the ampullary and prostatic ducts.

**Habits:** One specimen was found under an intertidal rock on the northern lagoonward side of Chinimi Island, Eniwetok Atoll. The food was not determined but the structure and form of the digestive tract suggest that this species is a rasping sponge-feeder.

**Remarks:** The occurrence of this specimen at Eniwetok Atoll is the northernmost record for *Chromodoris geometrica*, which was previously reported only from New Caledonia (RISBEC, 1928, 1953) and New South Wales (ALLAN, 1947).

*Chromodoris lilacina* (GOULD, 1852)

*Doris lilacina* GOULD, 1852: 297

*Doris amabilis* KELAART, 1859: 294 - 295

*Chromodoris porcata* BERGH, 1888: 831 - 833

*Chromodoris amabilis* (KELAART), ELIOT, 1906: 642, pl. XLII, fig. 1

*Glossodoris amabilis* (KELAART), PRUVOT-FOL, 1951: 84

**Description:** External morphology and coloration of one specimen are described by GOULD (1852). The reproductive system and the radular teeth in addition to further descriptions of external morphology are presented and figured by KAY & YOUNG (in preparation).

**Habits:** Two specimens (8 and 14 mm long) were collected on separate occasions from 0.5 m of water at the lagoon side of the northern end of Chinimi Island, Eniwetok Atoll. The food was not determined. Specimens of *Chromodoris lilacina* in Hawaii feed on *Mycale maunakea* DE LAUBENFELS, 1951, a sponge not reported from Eniwetok (unpublished data).

**Remarks:** The species described by KELAART (1859) as *Doris amabilis* and suggested by PRUVOT-FOL (1951) to be a glossodorid, probably is synonymous with *Chromodoris lilacina*. ELIOT (1906) figured the original of KELAART and suggested that it may be a chromodorid. ELIOT further suggested the synonymy of *C. porcata* (BERGH, 1888) with *C. amabilis*.

Specimens of *Chromodoris lilacina* are reported from Ceylon (KELAART, 1859), Mauritius (BERGH, 1888) and Hawaii (GOULD, 1852).

*Chromodoris albopustulosa* (PEASE, 1860)

*Doris albopustulosa* PEASE, 1860: 30

*Chromodoris albopustulosa* (PEASE), BERGH, 1884: 70

*Glossodoris albopustulosa* (PEASE), PRUVOT-FOL, 1947: 108; PRUVOT-FOL, 1951: 83

**Description:** The external characters of *Chromodoris albopustulosa* are described by PEASE (1860). External morphology, reproductive system, and radular teeth are

further described and figured by KAY & YOUNG (in preparation).

**Habits:** One 10 mm specimen was collected under a rock in 2 m of water in the quarry on Eniwetok Island. The structure and form of the alimentary tract suggest that this species is a rasping sponge-feeder, although the food was not determined.

**Remarks:** The occurrence of this specimen at Eniwetok Atoll is the only definite record of *Chromodoris albopustulosa* outside of the Hawaiian Islands (PEASE, 1860) as BERGH (1884) merely records it from the Pacific.

*Jorunna tomentosa* (CUVIER, 1804)

**Description:** A synonymy is given and external and internal characters are discussed by PRUVOT-FOL (1954). A specimen is figured by PRUVOT-FOL (1953). The reproductive system with its characteristic stylet is figured by BERGH (1880) and PRUVOT-FOL (1954). Additional descriptions of external and internal morphological characters are given and the radular teeth and the reproductive system are figured by KAY & YOUNG (in preparation) from specimens collected from the Hawaiian Islands.

**Habits:** One 18 mm specimen of *Jorunna tomentosa* was collected under a rock in 0.5 m of water on the northern lagoonward side of Chinimi Island. This species is reported to be a sponge-feeder in Europe (MILLER, 1961; THOMPSON, 1964) and Hawaii.

**Remarks:** *Jorunna tomentosa* is reported by PRUVOT-FOL (1954) to be distributed from 65° N latitude in Scandinavia down the coasts of Great Britain and France and into the Mediterranean Sea. This species is the only dorid collected which is not restricted in distribution to the Indo-West-Pacific faunal region. The occurrence of specimens of *J. tomentosa* in European waters as well as in Pacific waters suggests a cosmopolitan distribution.

DENDRODORIDIDAE

*Dendrodoris nigra* (STIMPSON, 1855)

**Description:** A synonymy is given and external morphological characters of adult specimens are described by MARCUS & BURCH (1965). External and internal morphological characters of this common Indo-West-Pacific dorid throughout different stages of its growth are described and figured by KAY & YOUNG (in preparation).

**Habits:** Twelve specimens of *Dendrodoris nigra* (4 to 30 mm long) were collected during the 3 week period: 9 from the quarry on Eniwetok Island and 3 from the northern lagoonward side of Chinimi Island. All specimens were black with white spots except for the smallest which

was orange and similar in coloration to juvenile specimens of *D. nigra* in Hawaii. One specimen (12 mm preserved length) was also collected on a head of *Porolithon* sp. inside the fringing reef at Johnston Island in August, 1965.

**Remarks:** Although there were no direct observations of feeding, fluorescence-microscopical examinations of material from the gut and feces indicated a complete absence of organic matter of plant origin with the exception of several errant diatoms. Lacking radular teeth, these specimens are probably sucking sponge-feeders as are those in Hawaii.

*Dendrodoris nigra* is not only one of the most abundant dorid species in Hawaii and at Eniwetok, but also one of the most widely distributed and frequently recorded dorids in the Indo-West-Pacific. This is the only species of dorid collected which has been previously recorded from Eniwetok. MARGUS & BURCH (1965) report 13 specimens of *D. nigra* collected on Parry and Japtan Islands, Eniwetok Atoll, during Spring 1960.

#### POLYGERIDAE

##### *Gymnodoris citrina* (BERGH, 1877)

(Text figures 16 to 18)

*Trevelyana citrina* BERGH, 1877: 440 - 443; plt. 56, figs. 18 - 25

**Description:** *Gymnodoris citrina* has a limaciform body measuring 6 to 24 mm long (Figure 16). The dorsum, which is cream or light yellow with small orange tipped pustules, is sparsely scattered with irregularly shaped epidermal spicules which are  $120\mu$  to  $250\mu$  in length and pointed at one or both ends. Anteriorly there is a broad cephalic hood edged with orange tipped serrations. In dorsal view the lobiform oral tentacles project anterolaterally beyond the edge of the cephalic hood, the genital orifice protrudes from the right side of the body immediately anterior to the level of the branchiae and the body tapers posteriorly with the elongate foot. The rhinophores, positioned laterally in the cephalic hood, are club-like in shape, bear 15 to 20 light yellow lamellae and may be tipped with orange. The 8 to 9 branchiae, in a horseshoe-shaped placement about the mid-dorsal anus, are simply pinnate, flattened laterally and smaller posteriorly; they are light yellow and often tipped with orange. Characteristically, but macroscopically visible only in large specimens, is a slightly raised V-shaped area edged with shallow, orange tipped serrations projecting and tapering posteriorly from the level of the branchiae to the posterior one-third of the body.

The radular formula of 3 specimens (6, 10, and 24 mm) is  $10-18 \times 14-30 \cdot 0-14-30$  (Figure 17). The first lateral tooth is simply hamate and larger than the succes-



Figure 16

*Gymnodoris citrina*  
Dorsal view of adult specimen

sive teeth in each row, varying from  $142\mu$  to  $390\mu$  long in 6 mm and 24 mm specimens respectively. The second lateral tooth is awl-shaped and broadly based, whereas the following teeth are successively narrower and shorter. At the buccal lip are paired unarmored cuticular thickenings.

Three ovate, orange-red ovotestes lie anteroventral to the digestive gland. Components of the genital mass were not discernible in the specimens dissected, excepting the long and tightly convoluted male duct system. Numerous cirral hooks,  $7\mu$  to  $8.5\mu$  long, line the lumen of the ejaculatory duct (Figure 18).

**Habits:** Six specimens were collected at Eniwetok Atoll. One was found in the quarry on Eniwetok Island and 5 on the northern lagoonward side of Chinimi Island under rocks in 0.5 m of water. An egg mass containing late stage veliger larvae,  $150\mu$  to  $162\mu$  in diameter, with an opisthobranch larval shell type 1 (terminology according to THOMPSON, 1961) was the only identifiable food found in the midgut of one specimen of *Gymnodoris citrina* collected in the field. One conclusion resulting from the category of this larval shell type is that the veligers are not of aeolid origin, as aeolids have a different type of larval

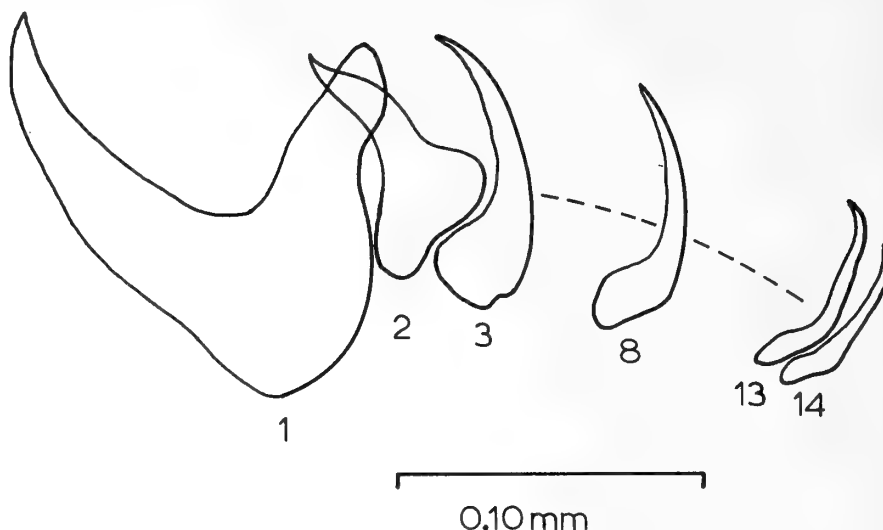


Figure 17

*Gymnodoris citrina*

Lateral view of right half row of radular teeth

1 = innermost lateral    2 = second lateral . . .  
14 = outermost lateral

shell from that of other opisthobranchs. A 10 mm specimen devoured a 6 mm specimen in the laboratory but this occurrence was probably induced by unnaturally crowded conditions in the aquarium.

**Remarks:** Since the name *Trevelyana* (= *Gymnodoris*) *citrina* was first proposed by BERGH (1877) for an 11 mm specimen from the Palau Islands, it has been put into the synonymy of *Gymnodoris bicolor* (ALDER & HANCOCK, 1866) by a number of workers (e. g. RISBEC, 1953; MACNAE, 1958; BABA, 1960). Comparison of internal and external characters of *G. bicolor* and *G. citrina* indicates that the two species are distinct.

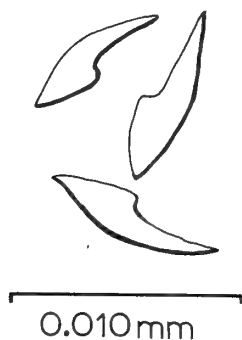


Figure 18

*Gymnodoris citrina*  
Cirral hooks

Much of the difficulty and confusion which have arisen concerning *Gymnodoris bicolor* and *G. citrina* are apparently because the first lateral tooth is larger in relation to the succeeding outer lateral teeth in both species. A comparison also reveals that the innermost laterals of *G. citrina* are much larger than those of *G. bicolor* in similar sized specimens. In fact, the 120 $\mu$  length of the innermost lateral tooth in a 22 mm specimen of *G. bicolor* from Hawaii (KAY & YOUNG, in preparation) is even shorter than the 142 $\mu$  length of the similar tooth in a 6 mm specimen of *G. citrina* from Eniwetok.

The broad base and awl-shaped cusp of the second lateral tooth is a useful specific character for *Gymnodoris citrina* as stated by BERGH (1877). The 180 $\mu$  length of the innermost lateral tooth from the 11 mm specimen of BERGH also agrees favorably with the 165 $\mu$  length of the similar tooth from a 10 mm specimen in this study.

RISBEC (1928) described two species of *Trevelyana* (= *Gymnodoris*), *T. perlucens* and *T. suggens*, from New Caledonia. Both were later put into the synonymy of *T. bicolor* (RISBEC, 1953). In the latter work, RISBEC describes "un nouvel exemplaire," literally "a new specimen," which he states is intermediary in certain characters to the *T. perlucens* and *T. suggens* "forms" of *T. bicolor*. This new specimen described by RISBEC (1953) exhibits many diagnostic characters of *G. citrina*. Among the common ones are: "... papilles oranges disposées en V en arrière des branchies et les encadrant ... plaques

cornées incolores situées en avant de la rotella ... La 1<sup>re</sup> latérale a une cuspidé de 0.24 mm de long ... La glande génitale est formée de trois masses arrondies d'un rouge foncé ... le canal déférent est plus long." (RISBEC, 1953, pp. 100 - 101). The specimen figured by RISBEC (1953, fig. 57) bears a greater resemblance to *G. citrina* than to *G. bicolor*.

Although only one specimen of *Gymnodoris citrina* has been reported from the Palau Islands (BERGH, 1877), the species is likely to be further distributed throughout the Indo-West-Pacific faunal region. Because past species descriptions have not always been sufficient to enable one to distinguish between *G. citrina* and *G. bicolor*, the distributions of both species remain uncertain.

#### VAYSSIÉREIDAE

##### *Okadaia elegans* BABA, 1930

**Description:** Synonymies are given and certain aspects of the biology of *Okadaia elegans*, including descriptions of the external and internal morphology, are discussed by BABA (1937).

**Habits:** Numerous specimens of *Okadaia elegans* were found in the shallow tide pool at the northern lagoonward side of Eniwetok Island. These minute limaciform dorids with a maximal length of 4 mm were found feeding on spirorbid polychaetes on the undersides of rocks in the area. In penetrating the calcareous exoskeleton of a spirorbid polychaete, *O. elegans* bores a hole through the tube with its radular teeth.

The egg masses of *Okadaia elegans* were deposited as flattened gelatinous masses on the undersides of rocks at the collecting site and on the sides of aquaria in the laboratory. Juvenile forms, 0.55 mm to 0.70 mm long, emerge from individual capsules contained in each egg mass within 10 days after oviposition at 26° to 27° C and feed upon spirorbid polychaetes in a similar manner as the adult forms.

**Remarks:** Previously reported from Japan (BABA, 1930, 1931, 1937) and commonly found in Hawaii, this species is likely to be found throughout the Indo-West-Pacific faunal area if a careful examination is made of substrata colonized by spirorbid polychaetes. Specimens of *Okadaia elegans* are likely to be overlooked because of their small sizes. Species closely allied to *O. elegans* have been reported from New Caledonia (RISBEC, 1928), New Zealand (RALPH, 1944), and Formosa (COLLINGWOOD, 1881).

#### AEOLIDACEA

##### FAVORINIDAE

##### *Herviella mietta* MARCUS & BURCH, 1965

**Description:** MARCUS & BURCH (1965) discuss external and internal morphological characters, and figure an adult specimen, a radular tooth, a jaw and a penial stylet in their original description of *Herviella mietta* from 16 specimens from Eniwetok.

**Habits and Remarks:** Twelve specimens of *Herviella mietta* (5 mm to 10 mm long) were collected intertidally on the northern lagoonward side of Eniwetok Island, the same location where 13 specimens were collected in 1960 (MARCUS & BURCH, 1965). A single 8 mm specimen was also collected intertidally under a rock on the western lagoon side of Igurin Island, the only nudibranch collected at this island.

Numerous egg masses of *Herviella mietta* were deposited in the collecting area on the undersides of rocks and even on the shells of specimens of the prosobranch, *Cerithium sejunctum* IREDALE, 1929. The larvae pass the veliger stage within the egg mass and each emerges in the crawling stage with the larval shell yet attached within 6 days after oviposition at 28° to 29° C. Within 24 hours after hatching the larval shells are dropped. The juvenile forms bear 2 simple cerata.

Unreported in the description of the species is the feeding of *Herviella mietta* on the eggs of the prosobranch gastropod *Cerithium sejunctum*. This association is likely to be a seasonal occurrence during the spawning of *C. sejunctum* and the aeolid is probably a hydroid-feeder during the remainder of the year. Additional evidence that another food is eaten by these aeolids is that newly hatched juveniles of *H. mietta* do not feed on the eggs of *C. sejunctum*. Variation from a hydroid diet by aeolids is reported in England for *Calma glaucoides* (ALDER & HANCOCK, 1855) which feeds on demersal fish eggs (EVANS, 1922; ROWETT, 1946) and in Hawaii where an unidentified species of aeolid feeds on the eggs of the opisthobranch gastropod *Aplysia juliana* QUOY & GAIMARD, 1832 (E. Alison Kay, personal communication).

Specimens of *Herviella mietta* were the only nudibranchs eaten by a butterfly fish (*Chaetodon auriga*) which was kept in a large sea water tank in the Eniwetok Marine Biological Laboratory. All other nudibranchs collected were rejected after they were initially taken into the mouth of the fish. The nudibranchs were not visibly harmed by such treatment and thereafter were not taken in by the fish after an initial investigation. Specimens of *H. mietta* were readily eaten by the fish on every occasion,

even when the fish was fed to apparent satiation with other food. This is one of the few occasions that possible predation on aeolid nudibranchs by fish has been demonstrated (see EDMUNDS, 1966).

*Herviella claror* BURN, 1963

**Description:** MARCUS & BURCH (1965) expanded on the description of *Herviella claror* BURN, 1963 and figured an adult specimen, a radular tooth and a jaw on the basis of 3 specimens collected from Eniwetok.

**Habits and Remarks:** Two specimens (13 mm and 15 mm long) of *Herviella claror* were found in the quarry on Eniwetok Island not far from the north end of the same island where 3 specimens were collected in 1960 (MARCUS & BURCH 1965). This species was described from a specimen collected in New South Wales (BURN, 1963).

### SUMMARY

Nine new geographic records, 3 confirmatory geographic records and one new species, *Hypselodoris kayae*, representing 2 superfamilies and 5 families of the Nudibranchia are reported from 3 atolls (Eniwetok, Palmyra and Johnston Island) in the Central and West-Central Pacific. With one exception of a presumed cosmopolitan species, *Jorunna tomentosa*, all the nudibranchs are limited in distribution to the Indo-West-Pacific faunal region. Six species co-occur in Hawaii and Eniwetok.

Only 1 of the 7 species of Doridacea previously reported from Eniwetok was found. This difference probably reflects the seasonality in occurrence of dorids in shallow water. The 2 species of Aeolidacea previously reported from Eniwetok are verified.

The foods of 3 sponge-feeders, *Doriopsis viridis*, *D. pecten*, and *Hypselodoris kayae*, and one polychaete feeder, *Okadaia elegans*, are reported. Two occurrences of predation by nudibranchs on egg masses of gastropods are given. It is verified that specimens of *Herviella mietta* feed on egg masses of a prosobranch gastropod and suggested that specimens of *Gymnodoris citrina* feed on egg masses of an unknown opisthobranch gastropod.

Three general types of larval development are shown by the nudibranchs collected. The larvae of *Doriopsis viridis* and *Hypselodoris kayae* emerge from egg masses as free swimming veligers. The larvae of *Herviella mietta* hatch as crawling larvae that drop their shells within 24 hours. The larval stages of *Okadaia elegans* are completed within egg masses from which emerge juveniles that are capable of adult feeding habits.

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# A Re-Interpretation of the Sand-Pipes Described by ADEGOKE

BY

JOHN W. EVANS

Department of Biology

Memorial University of Newfoundland, St. John's, Newfoundland, Canada

(Plate 17)

ADEGOKE (1966) DESCRIBED A NUMBER of silicified sand and mud-filled pholad burrows in Upper Miocene strata from San Luis Obispo County, California. The rock into which the burrows were bored belongs to the Monterey Formation and is described by ADEGOKE as a "hard, dull, greenish-brown, siliceous and cherty mudstone." The Monterey Formation is overlain by a "whitish-gray, fine-grained and tuffaceous silty sandstone" of the Pismo Formation, which fills the burrows, forming the "sand-pipes."

As I have recently been engaged in the study of the ecology of living pholads, I would like to discuss his findings and to offer some alternative interpretations.

ADEGOKE tentatively assigned the fossil pholad to the genus *Chaceia* (?). While on the available evidence this identification cannot be ruled out, it should be pointed out that the characters used to identify the genus are not definitive.

One of the principal characters used was the short sub-spherical outline of the valves. Unfortunately, ADEGOKE does not give a numerical value for the ratio: valve length to depth. Measurements made by TURNER (1955) show that adult *Chaceia ovoidea* (GOULD, 1851) with a length to depth ratio range of 1.46 - 1.88 could be confused with a number of the Pacific Coast pholads on the basis of this character. This is especially true of *Penitella fitchi* TURNER, 1955, with a ratio ranging from 1.1 to 1.9 and *Zirfaea pilsbryi* LOWE, 1931, with ratios from 1.5 to 2.1 (TURNER, 1954). In the vicinity of Coos Bay, Oregon, adult *Penitella penita* (CONRAD, 1837) have been collected by the author with a length to depth ratio ranging from 1.55 to 2.56. Young, actively boring animals

are significantly shorter than the adults, with the ratio ranging all the way down to 1.0 in the newly settled forms.

Another character used by ADEGOKE to identify *Chaceia* was the thinness of the walls of the valves. Because valve thickness is a highly variable characteristic even within a single species, it is not a useful characteristic for identifying pholad genera. The valve thickness of *Penitella penita* varies from very thin in soft rock to very thick in hard rock (EVANS: A, in press).

The presence of a pedal gape is characteristic of all young Pholadidae. The callum which partially or wholly closes the pedal gape of adult Martesiinae is usually very delicate and is the first portion of the shell to dissolve or break after death. Thus the numerous holes in the anterior region of the burrows could either be explained by the absence of a callum or by a broken callum.

The observation that "the faint lamellar ribs are not unlike those of *Chaccia*" does not help to identify the fossils because the lamellar ribs of all Martesiinae are basically very similar. On the other hand, within a single species (*Penitella penita*) the morphology of the lamellar ribs can vary considerably depending on the type of substrate inhabited by the animal (EVANS: A, in press and B, in preparation).

ADEGOKE described two types of burrows: elongate conical burrows with tapering necks and bulbous bottoms (similar to Figure 1, Plate 17) and small spherical burrows with or without short slender necks (similar to Figure 2, Plate 17).

Most pholads drill conical burrows, similar to the first type. With the present state of our knowledge about pholad

## Explanation of Plate 17

Figure 1: *Penitella penita* valves and cast of burrow

Figure 2: *Nettastomella rostrata* valves and cast of burrow

Note: Base of burrow incomplete in both cases



Figure 1

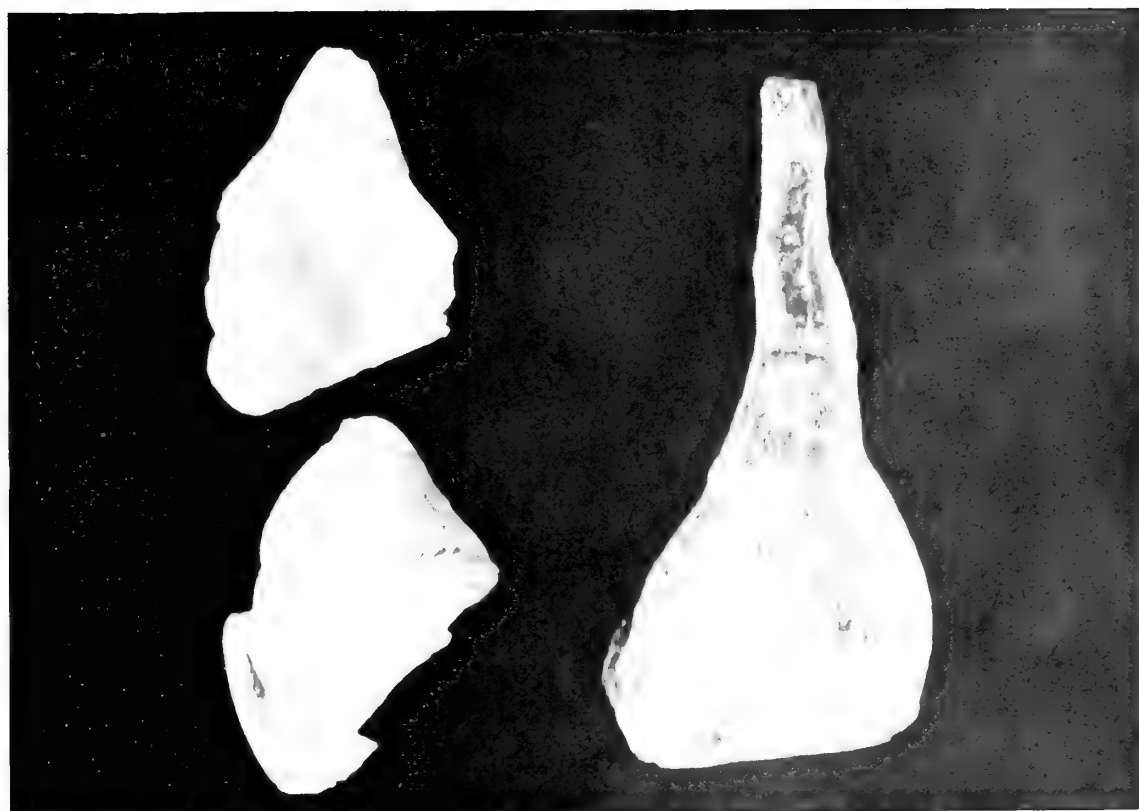


Figure 2

Scale  $3\frac{1}{3} : 1$



burrow morphology, no clue as to the former occupant can be obtained from this information alone.

With respect to the spherical slender-necked burrows (ADEGOKE, plate 21, figures 8 and 5) a more informed guess can be made about the identity of the original occupant. This burrow shape is very different from the usual pholad burrow and has only been observed by the author in one species, *Nettastomella rostrata* (VALENCIENNES, 1846). The cast of a burrow of a living *N. rostrata* from near Fossil Point in Coos Bay, Oregon, is illustrated in Plate 17, Figure 2. Note the similarity both of size and shape to the burrows shown by ADEGOKE. It is almost certain that the same species did not form both of the burrow types described by ADEGOKE. The burrow of *Penitella penita* varies somewhat with age and significantly with differences in substrate hardness; nevertheless the conical shape is always retained (EVANS, in preparation C). An examination of figure 9, plate 21 of ADEGOKE's paper will show that there is a conical burrow on the left side of the hand specimen which is considerably smaller than either of the spherical burrows in figures 5 and 8; thus his contention that the spherical burrows are formed by young animals is open to question.

ADEGOKE states that *Chaceia ovoidea*, *Penitella penita*, *Penitella gabbi* (TRYON, 1863), *Parapholas californica* (CONRAD, 1837) are all capable of burrowing into extremely hard rock and even into concrete. TURNER (1955) states that *C. ovoidea* lives in soft shale, that *Parapholas californica* is found in clay, shale and soft friable stone; she does not say in what kind of rock *Penitella gabbi* is found. *Penitella gabbi* is quite common in the soft sandstone rock of the Empire Formation near Fossil Point in Coos Bay, Oregon, but is not found in harder rocks nearby which are, however, bored by *Penitella penita*. Only *P. penita* of all Pacific Coast pholads is capable of boring extremely hard rocks.

The rock into which these burrows are drilled is reported to be hard, siliceous and cherty. If, as ADEGOKE seems to imply, the rock in the late Miocene period was as hard as it is today, only *Penitella penita* or an extinct but equally tenacious borer could have made these burrows. However, there is considerable evidence to suggest that at the time of the boring, the Monterey Formation rock was a relatively soft shale with a high silica content probably, as BRAMLETTE (1946) suggests, in the form of diatom skeletons. BRAMLETTE (*op. cit.*) claims that the present hard cherty character of the rock is due to the solution and subsequent redeposition of diatomaceous silica.

ADEGOKE's description of the dull glassy nature of the burrows and their contents supports this suggestion.

The thinness of the valves is another indication of the softness of the rock at the time of burrowing. In my studies of living *Penitella penita*, animals with thin-walled valves were always associated with soft rock.

If my claim is correct that the spherical burrows were formed by *Nettastomella rostrata*, this is further evidence that the rock in late Miocene was very soft. TURNER (1955) states that *N. rostrata* is found in soft shale and mud shale. In the Coos Bay region this species was found in considerable numbers in very soft shale dredged from deep water and more rarely collected intertidally in very friable sandstone.

If the identity of the pholad which formed the conical burrows could be established with confidence, the relative hardness of the rock at the time it was being bored could be estimated by analysis of burrow shape (EVANS, in preparation, C) and this could be compared with its present hardness. A method for estimating the relative hardness of sedimentary rock is described in another paper (EVANS, in preparation, C).

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# The Reproductive System of the British Turridae

(GASTROPODA : TOXOGLOSSA)

BY

EDMUND H. SMITH

Department of Zoology, University of Glasgow, and the Marine Station, Millport<sup>1</sup>

(Plate 18; 16 Text figures)

THAT THE NEOGASTROPODS exhibit a similar organization in their reproductive systems has been well illustrated in the families Muricidae, Buccinidae and Nassariidae (FRETTER, 1941; JOHANSSON, 1942, 1957; FRETTER & GRAHAM, 1962). Few species have been described from the families Conidae, Terebridae, Olividae, Columbellidae and Turridae (RISBEC, 1955; MARCUS, 1959, 1960, 1962; ROBINSON, 1960) and the aim of the present paper is to provide a more detailed account of the reproductive system of the Turridae than has been published hitherto. The species examined were *Haedropleura septangularis* (MONTAGU, 1803); *Philbertia leufroyi boothi* (SMITH, 1839); *Cenodagreutes aethus* E. H. SMITH, 1967; *Cenodagreutes coccyginus* E. H. SMITH, 1967; *Mangelia attenuata* (MONTAGU, 1803); *Lora trevelliana* (TURTON, 1834); *Lora turricula* (MONTAGU, 1803). This last species is of particular interest since it exhibits a form of protandric consecutive sexuality which has not been previously recorded in the Prosobranchia.

## METHODS

The animals were removed from their shells, relaxed in propylene phenoxetyl (OWEN, 1955) and fixed in Bouin's or Gilson's fluid. The fixed material was sectioned and stained with Alcian blue, haemalum and eosin. Heidenhain's iron haematoxylin and Mallory's triple stains were used for the study of the glandular parts of the reproductive system.

## MALE REPRODUCTIVE SYSTEM

In the typical male reproductive system (Figure 1) the testis (t) shares part of the visceral mass with the digestive diverticula (dd) which may even be partly displaced

during the height of the reproductive period. The testicular duct leaves the testis and progresses along the columella muscle to enter the prostate gland (pg) at the posterior end of the mantle cavity. This duct can be divided into the vesicula seminalis which is the portion nearest the testis and the vas deferens (vd) which is the narrow part entering the prostate gland. The vesicula seminalis is dis-

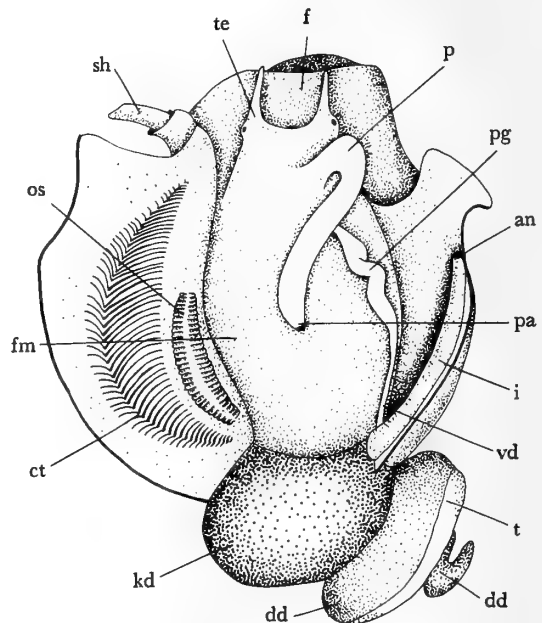


Figure 1

### Typical Male System

an - anus	ct - ctenidium	dd - digestive diverticula
f - foot	fm - floor of mantle cavity	i - intestine
kd - kidney	os - osphradium	p - penis
pg - prostate gland	pa - opening of penis	t - testis
sh - siphon	te - tentacles	vd - vas deferens

<sup>1</sup> Present address: Pacific Marine Station, Dillon Beach, California 94929.

tended with sperm during the breeding season and sometimes functions in the ingestion of excess sperm. In some species a gonopericardial duct or a connective tissue remnant of the duct joins the vas deferens with the pericardium. The convoluted prostate gland lies on the left side of the mantle cavity (fm) and in some species incomplete fusion of the two lobes of the gland leaves an opening into the mantle cavity. A duct leads from the prostate to the base of the penis (p) and then continues along the length of the penis to open at its tip. The penis itself lies along the left side of the mantle cavity and in some species actually curves to the right along the posterior limit of the cavity.

### *Haedropleura septangularis*

The thin wall of the long, folded vesicula seminalis of *Haedropleura septangularis* (Figure 2, vs) is composed of

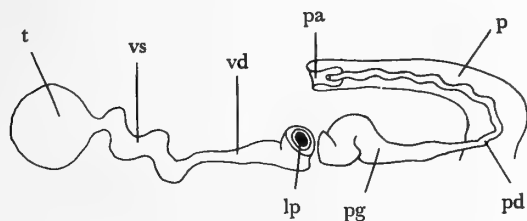


Figure 2

### *Haedropleura septangularis*

Diagrammatic Reconstruction from Sections of the Male System

lp - lumen of prostate gland    p - penis    pa - opening of penis  
pd - duct from prostate    pg - prostate gland    t - testis  
vd - vas deferens    vs - vesicula seminalis

a low epithelium surrounded by connective tissue; no sperm ingestion was found. The vas deferens (vd), as it leaves the vesicula seminalis (vs) is lined by glandular cells which contain small, yellow particles concentrated along their apical borders. No gonopericardial duct nor any remnant of one could be found. After the vas deferens leaves the area of the pericardium it narrows, becomes heavily ciliated, and is surrounded by a thick muscular layer. The long prostate gland (pg) which extends from the area of the kidney, through the ventral floor of the cephalic haemocoele, to the penis (p), is convoluted with an indistinct midventral line of fusion between its two lobes; no opening into the mantle cavity could be found. The ciliated epithelium lining the lumen of the gland (lp) is underlain by a layer of circular muscles and also present are subepithelial gland cells of two types: mucous cells which form the dorsal portion of the gland and clusters of large, darkly staining cells which form the ventral

part. These latter cells contain refractile inclusions throughout their cytoplasm and open into the lumen by long ducts which pass through the circular muscles and between the ciliated cells.

The convoluted duct from the prostate gland (pg) to the tip of the penis (pa) is ciliated and surrounded by a thin, muscular layer. The large penis (p) reaches far into the mantle cavity with its tip turning to the right along the posterior limit. The spermiduct does not open directly at the tip of the penis but into a shallow cavity formed by the inpocketing of the two muscle layers. The penis is covered by a layer of cuticular cells interspaced by scattered mucous cells.

In view of the fact that most of the male turrids studied exhibit a similar pattern in their reproductive systems, the following species will be briefly compared to *Haedropleura septangularis*.

### *Philbertia leufroyi boothi*

In contrast to *Haedropleura septangularis* the vesicula seminalis of *Philbertia leufroyi boothi* (Figure 3, vs) is covered by a thick layer of circular muscle and lined with a glandular epithelium which is engaged in ingesting sperm. The sperm is attached to the apical pole of the

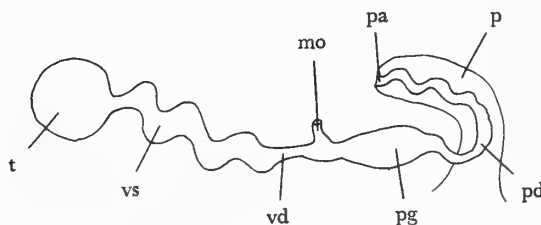


Figure 3

### *Philbertia leufroyi boothi*

Diagrammatic Reconstruction from Sections of the Male System

mo - opening from vas deferens to mantle    p - penis  
pa - opening of penis    pd - duct from prostate  
pg - prostate gland    t - testis    vd - vas deferens  
vs - vesicula seminalis

ingesting cells where it is engulfed and deposited in small vacuoles. The epithelium of the vas deferens (vd) is composed of short, ciliated, columnar cells resting on a thick basement membrane and the muscular layer below this membrane is thinner than that surrounding the vesicula seminalis. An opening into the mantle cavity which sometimes occurs when there is incomplete fusion of the lobes of the prostate gland is, in this species, at the end of a short, ciliated duct (mo) from the vas deferens (vd) where the vas deferens joins the prostate gland (pg). The

histology of the prostate gland (pg) is similar to that of *H. septangularis* although there are no mucous cells and no line of fusion between the two lobes.

#### *Cenodagreutes aethus*

The vesicula seminalis (Figure 4, vs) of *Cenodagreutes aethus* is not ciliated. The area near the testis (t) is glandular, while the remaining portion of the vesicula seminalis was distended with sperm, making it difficult to ascertain the nature of the epithelium. The vas deferens

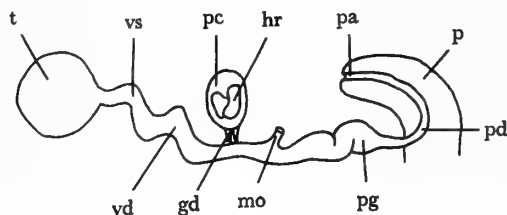


Figure 4

#### *Cenodagreutes aethus*

Diagrammatic Reconstruction from Sections of the Male System  
 gd - gonopericardial duct                      hr - heart  
 mo - opening from vas deferens to mantle                      p - penis  
 pa - opening of penis                      pc - pericardial wall  
 pd - duct from prostate                      pg - prostate gland                      t - testis  
 vd - vas deferens                      vs - vesicula seminalis

(vd) is narrow and convoluted with an epithelium composed of ciliated, cuboidal cells that rest on a thick layer of circular muscle. Contrary to the preceding turrids there is a remnant of the gonopericardial duct (gd) in the form of a short, thick strand of connective tissue which joins the duct to the pericardial wall (pc). As in *Philbertia leufroyi boothi* a ciliated muscle duct (mo) opens into the mantle cavity from the vas deferens (vd). Whereas the prostate gland (pg) is similar to those in the previously described turrids, the densely ciliated duct (pd) to the tip of the penis (p) differs in being muscular; also the penis is round, and not dorsoventrally flattened.

#### *Cenodagreutes coccyginus*

The few specimens collected of this rare turrid were all females.

#### *Mangelia attenuata*

As was the case with *Cenodagreutes coccyginus*, all the specimens collected were females.

#### *Lora trevelliana*

The vesicula seminalis (Figure 5, vs) is glandular and composed of cells with yellow granules of different sizes and shapes scattered throughout the cytoplasm. The densely

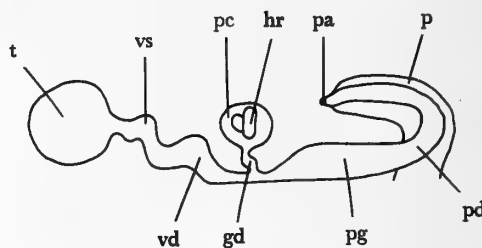


Figure 5

#### *Lora trevelliana*

Diagrammatic Reconstruction from Sections of the Male System  
 gd - gonopericardial duct                      hr - heart                      p - penis  
 pa - opening of penis                      pc - pericardial wall  
 pd - duct from prostate                      pg - prostate gland                      t - testis  
 vd - vas deferens                      vs - vesicula seminalis

ciliated vas deferens (vd) is narrow and gives off a long gonopericardial duct (gd) which opens into the pericardium (pc) through a ciliated funnel. The prostate gland (pg) is composed of the usual three cell types although the gland cells are not subepithelial. As in *Haedropleura septangularis* there is no opening from the prostate to the mantle cavity. The duct (pd) from the prostate (pg) to the penis (p) is glandular and composed of large, vacuolated cells interspaced by small, ciliated cells. This type of epithelium continues along the large penis almost to the tip where it becomes heavily ciliated and not glandular. A sphincter surrounds the opening of the duct at the tip of the penis.

## FEMALE REPRODUCTIVE SYSTEM

In the typical female reproductive system (Figure 6) the ovary (o) shares part of the visceral mass with the digestive diverticula (dd). A gonadal oviduct (go) leaves the ovary and runs along the inner surface of the viscera next to the columella muscle to join the renal portion of the oviduct (ro) which passes close to the pericardium and in some species gives off a duct to the pericardial cavity. This region of the oviduct enters a large, convoluted albumen gland (al) which opens in turn into the capsule gland (cg) through a short pallial oviduct. In some species

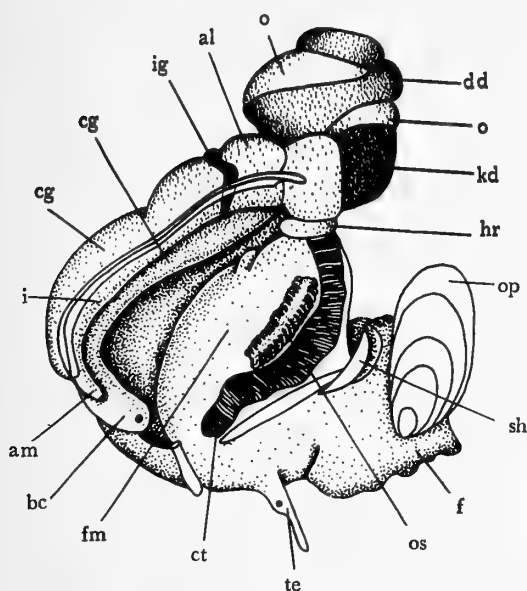


Figure 6

## Typical Female System

al – albumen gland	an – anus	bc – bursa copulatrix
cg – capsule gland	ct – ctenidium	dd – digestive diverticula
f – foot	fm – floor of mantle cavity	hr – heart
i – intestine	ig – ingesting gland	kd – kidney
op – operculum	os – osphradium	sh – siphon
	te – tentacles	

a receptaculum seminis and ingesting gland (ig) lie between the albumen gland and capsule gland. A duct connects the receptaculum with the pallial oviduct. The capsule gland is the largest organ of the female system and lies along the left side of the mantle cavity. This gland opens into the bursa copulatrix (bc) which in turn opens into the mantle cavity slightly anterior to the anal opening (an).

*Haedropleura septangularis*

The gonadal oviduct (Figure 7, go) is composed of columnar gland cells with a lightly staining basal ergastoplasm and is surrounded by a thick muscular layer. No evidence of egg yolk absorption was found (FRETTER, 1941).

The renal oviduct (ro) is short, narrow, and enters the albumen gland (al) ventrally. There is no gonopericardial duct.

The large albumen gland has a ciliated lumen (la) that is partially divided medially by a thin septum (sp) which extends halfway to the floor from its dorsal wall. The entire gland is surrounded by a thick muscular layer. The

anterior end of the gland opens into the capsule gland (cg) through a very short, ciliated pallial oviduct (po).

The large ingesting gland (ig) lies between the albumen (al) and capsule glands (cg) and extends for a short

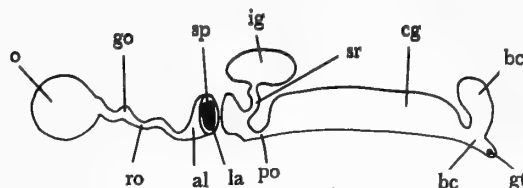


Figure 7

*Haedropleura septangularis*

## Diagrammatic Reconstruction from Sections of the Female System

al – albumen gland	bc – bursa copulatrix	cg – capsule gland
go – gonadal oviduct	gt – genital opening	ig – ingesting gland
la – lumen of albumen gland	o – ovary	po – pallial oviduct
ro – renal oviduct	sp – septum	sr – receptaculum seminis

distance over the dorsal surface of the latter. The gland is not attached to the pallial oviduct (po) but to the anterior end of the albumen gland (al) by a long, narrow, ciliated duct which acts as a receptaculum seminis (sr). This fact would indicate that the most likely place for fertilization would be in the albumen gland (al) and not in the pallial oviduct (po). The lumen of the ingesting gland is filled with oriented sperm cells arranged in convoluted rows and not attached to the walls. Some sperm ingestion does occur, but the epithelium is so thin that the amount of sperm ingested, when compared to the vast amount of sperm present in the lumen, must be small.

The capsule gland (cg), although somewhat more complex in its staining properties than those of the muricids and buccinids, is essentially similar in its morphology to that described by FRETTER & GRAHAM (1962) for *Thais lapillus*.

An elongated bursa copulatrix (bc) runs dorsad along the anterior end of the capsule gland (cg) and curves slightly posteriad at the distal end of the capsule gland. The bursa is lined anteriorly by a mucoid epithelium interspaced by small, ciliated cells. Further to the posterior the epithelium changes to a low, ciliated, cuboidal layer. Oriented sperm were attached to this ciliated epithelium, while unoriented sperm, mixed with mucus, filled the distal end of the bursa. The entire bursa copulatrix is covered by a thick layer of muscle.

*Philbertia leufroyi boothi*

The gonadal oviduct (Figure 8, go) from the ovary to the albumen gland (al) is short and surrounded by a thin

connective tissue layer; the lumen is lined by tall columnar cells which stain lightly with haemalum. The renal oviduct (ro) is also extremely short and enters the large, slightly elongated albumen gland (al) through a narrow opening that does not possess a sphincter.

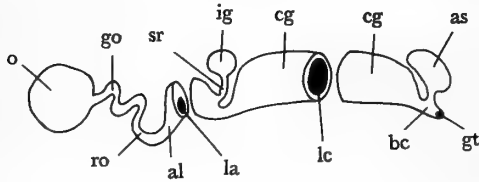


Figure 8

*Philbertia leufroyi boothi*

Diagrammatic Reconstruction from Sections of the Female System

al - albumen gland                      as - anterior sperm sac  
bc - bursa copulatrix      cg - capsule gland      go - gonadal oviduct  
gt - genital gland                      ig - ingesting gland  
la - lumen of albumen gland      lc - lumen of capsule gland  
o - ovary                      ro - renal oviduct                      sr - receptaculum seminis

The lumen of the albumen gland (al) is narrow, ciliated and lacks the septum present in *Haedropleura septangularis*. The dorsal half of the albumen gland is composed of clusters of mucous cells which open into the lumen through long protoplasmic processes. Lining the lumen (ls) and interspaced between the ciliated cells are other gland cells which stain deeply in haemalum. The ventral part of the albumen gland is of the same cellular organization except that the subepithelial gland clusters are not mucoid, but stain with haemalum and eosin.

As in *Haedropleura septangularis* a short, straight duct connects the ingesting gland (ig) with the anterodorsal wall of the albumen gland (al). The ciliated lumen of the duct is partially divided near its junction with the albumen gland by two opposing lateral folds. A sharp line of demarcation divides the epithelium of the duct from that of the ingesting gland. Although no oriented sperm were found in the duct (sr), the possibility that it acts as a receptaculum seminis cannot be ruled out.

The ingesting gland is composed of very large ( $200\mu$  to

$270\mu$  long and  $50\mu$  to  $120\mu$  wide) gland cells (Plate 18, Figure 1). These cells contain ingested sperm cells (is) which are in the process of disintegration. The cytoplasm surrounding the vacuoles containing the disintegrating sperm is filled with yellow granules which accumulate at the apical pole of the cell. A deeply staining, fibrous ergastoplasm (ep) forms a dark basal border while large, misshapen nuclei (pn) up to  $75\mu$  long, lie basally near the corners of the cells. The pronounced nuclear polymorphism may be due to endomitosis with endopolyploidy which is common in some invertebrates (GABE & ARVY, 1961). Partly disintegrated sperm (s) were found in the lumen of the gland.

The staining properties and ciliary currents of the capsule gland are not as complex as those of *Haedropleura septangularis* or those of the muricids and buccinids (FRETTER, 1941; personal observation).

In the albumen gland (al) lateral ciliary currents (Figure 9) beat into a strong central current which flows

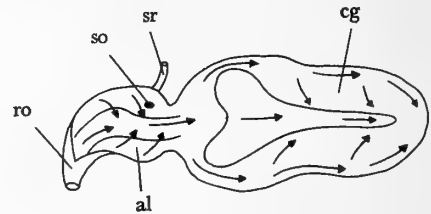


Figure 9

*Philbertia leufroyi boothi*

Diagram of the Ciliary Currents in the Capsule Gland

al - albumen gland      cg - capsule gland      ro - renal oviduct  
so - opening to receptaculum seminis      sr - receptaculum seminis

directly into the capsule gland (cg). Here anteriorly directed currents beat along the dorsal lips of the lobes and along the ventral suture while anteroventral currents beat over the middle of each lobe towards the main ventral current. The complex currents, which beat in opposite directions, found in the muricids and buccinids, are absent.

Since the ventral channel of the capsule gland is absent, the small bursa copulatrix (bc) opens directly into the

## Explanation of Plate 18

Figure 1

*Philbertia leufroyi boothi*

Cross Section of the Ingesting Gland

cg - capsule gland      ep - basal ergastoplasm      is - ingested sperm  
kd - kidney                      lc - lumen of capsule gland  
pn - polymorphic nuclei  
s - sperm                      sr - receptaculum seminis

Figure 2

*Philbertia leufroyi boothi*

Cross Section of the Anterior Sperm Sac

cg - capsule gland      es - epithelium of the anterior sperm sac  
i - intestine                      s - sperm





lumen of the capsule gland (lc). The tall epithelium lining the bursa contains ciliated cells with granular inclusions which are actively secreting into the lumen.

In contrast to *Haedropleura septangularis* a short, non-ciliated duct enters the dorsal surface of the bursa (bc) from a large, round "anterior sperm sac" (as) which lies near the anterior end of the capsule gland (cg). This sac is filled with oriented sperm (Plate 18, Figure 2) with their heads pointing towards the walls (es) of the sac but not in actual contact with the epithelium which consists of long, thin cells filled with granules and small vacuoles. No evidence of sperm ingestion could be found. A somewhat similar "sac," termed a "terminal pouch," was described by MARGUS (1960) in *Hastula cinerea*, but, whereas in this species it is situated anterior to the bursa copulatrix, in *Philbertia leufroyi boothi* it lies dorsally between the bursa and the capsule gland.

#### *Cenodagreutes aethus*

The gonadal and renal portions (Figure 10, go, ro) of the oviduct are similar to those of *Haedropleura septangularis*. The albumen gland (al) is ciliated throughout, but contrary to the preceding turrids, there are no subepithelial glands. Instead, large mucous cells interspaced with

ticity when stained with haemalum. The cells rest on a thin basement membrane which is in turn surrounded by a layer of connective tissue.

The capsule gland (cg) is similar to that of *Haedropleura septangularis*, although its staining properties are more complex. The bursa copulatrix (bc) is muscular with a narrow lumen which opens directly into the capsule gland as in *Philbertia leufroyi boothi*. The epithelium lining the capsule gland and extending a short way into the bursa is composed of gland cells which stain deeply in haemalum. This glandular epithelium rapidly gives way to a simple cuboidal layer of cells surrounded by thick ( $30\mu$  to  $60\mu$ ), circular muscles.

#### *Cenodagreutes coccyginus*

The female system of *Cenodagreutes coccyginus* is very similar to that of *C. aethus*, with some exceptions (Figure 11). There is a pallial oviduct (po) between the albumen gland and the capsule gland (cg).

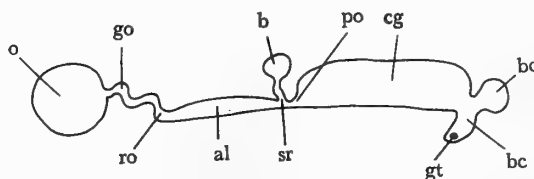


Figure 11

#### *Cenodagreutes coccyginus*

Diagrammatic Reconstruction from Sections of the Female System  
 al - albumen gland      b - bulb      bc - bursa copulatrix  
 cg - capsule gland      go - gonadal oviduct      gt - genital opening  
 o - ovary      po - pallial oviduct      ro - renal oviduct  
 sr - receptaculum seminis

No sperm were found in the small distal bulb of the receptaculum seminis (sr), nor was there any evidence of sperm ingestion. However, the possibility of sperm ingestion cannot be completely ruled out. The low epithelium lining the terminal bulb of the receptaculum seminis is composed of eosinophilic cells with irregularly shaped granules throughout the cytoplasm. The general histological and morphological data indicate that both bulb and duct function as a receptaculum seminis.

The bursa copulatrix (bc) is much larger than that of *Cenodagreutes aethus* with the bulb forming the distal end of the bursa and lying at the anterior end of the capsule gland (cg). The bulb, although it has become part of the bursa and functions in a different manner, lies in the same position as the "anterior sperm sac" of *Philbertia leufroyi boothi*. It is not lined by glandular epithelium, but by one composed of densely ciliated, cuboidal cells which rest on a thin layer of circular muscle.

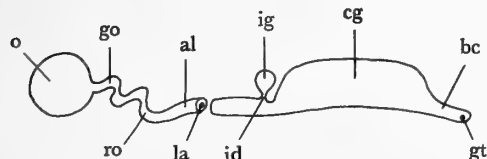


Figure 10

#### *Cenodagreutes aethus*

Diagrammatic Reconstruction from Sections of the Female System  
 al - albumen gland      bc - bursa copulatrix      cg - capsule gland  
 go - gonadal oviduct      gt - genital opening      ig - ingesting gland  
 id - duct to ingesting gland      la - lumen of albumen gland  
 o - ovary      ro - renal oviduct

ciliated cells form the dorsal wall of the gland while the much thinner ventral wall has only scattered mucous cells. The epithelium of the albumen gland (al) becomes continuous with the posterior part of the capsule gland (cg); a slight constriction rather than a duct marks the boundary between the two glands. Therefore, the pallial oviduct is absent.

A short, constricted, muscular duct joins the anterodorsal part of the albumen gland with the ingesting gland (ig) and functions as a receptaculum seminis (sr). The lumen of the ingesting gland is lined with gland cells possessing large, polymorphic nuclei that exhibit chroma-

*Mangelia attenuata*

The gonadal oviduct (Figure 12, go) is comprised of tall, glandular cells which are, for the most part, chromatophobic and in which there is a concentration of granules near the apical pole that stains with Alcian blue. In

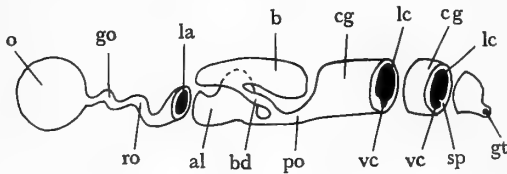


Figure 12

*Mangelia attenuata*

Diagrammatic Reconstruction from Sections of the Female System

- |                             |                             |                      |
|-----------------------------|-----------------------------|----------------------|
| al - albumen gland          | b - bulb                    | bd - duct to bulb    |
| cg - capsule gland          | go - gonadal oviduct        | gt - genital opening |
| la - lumen of albumen gland | lc - lumen of capsule gland | o - ovary            |
| po - pallial oviduct        | ro - renal oviduct          | sp - septum          |
| vc - ventral channel        |                             |                      |

contrast to the previously described turrids, a strong sphincter divides the renal oviduct (ro) from the albumen gland (al). This is ciliated throughout and as in both species of *Cenodagreutes* there are no subepithelial glands. The entire gland and the long pallial oviduct (po) connecting it with the capsule gland (cg) are covered by a thick sheet of muscle. The duct is lined by columnar cells bearing dense cilia.

Branching from the pallial oviduct is a long, muscular duct (bd) with a densely ciliated lumen similar to that of the pallial oviduct. This straight duct leads to a very large, elongated bulb (b) which lies over the dorsal surface of the albumen gland and is not branched as in *Mangelia brachystoma* (ROBINSON, 1960). The cells lining the bulb exhibit different stages of intracellular elaboration, culminating in the extrusion of a voluminous globule and they resemble the ingesting type of cell found in *Philbertia leufroyi boothi* in having large, polymorphic nuclei, although neither the duct nor the bulb contained sperm in any of the specimens sectioned and the nature of the epithelium does not suggest an ingesting function.

The capsule gland shows the same staining complexity found in both species of *Cenodagreutes*. As in *Mangelia brachystoma* (ROBINSON, 1960) no separate bursa copulatrix (bc) is present, but a large, ventral channel (vc), which is separated from the capsule gland by a septum (sp), extends posteriorly past the gonopore (gt) for some distance. The penis is inserted into this channel instead of a separate chamber as in the preceding turrids. The septum, which separates the anterior part of the ventral

channel from the capsule gland, disappears posteriorly so that the channel is marked only by a slight constriction.

*Lora trevelliana*

Whereas in most of the turrids studied the gonadal oviduct (Figure 13, go) is long, in this species it is short and ciliated and, in addition, the cells have a vacuolated cytoplasm with small granules concentrated around the cell walls. The long albumen gland is similar to that of both species of *Cenodagreutes* with some slight staining differences; the gland cells are not subepithelial. The elongated ingesting gland (ig) extends posteriorly over the dorsal surface of the albumen gland (al) and the cells lining the duct to the ingesting gland are densely ciliated,

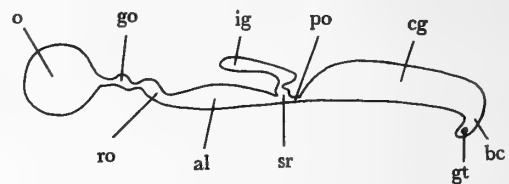


Figure 13

*Lora trevelliana*

Diagrammatic Reconstruction from Sections of the Female System

- |                      |                           |                      |
|----------------------|---------------------------|----------------------|
| al - albumen gland   | bc - bursa copulatrix     | cg - capsule gland   |
| go - gonadal oviduct | gt - genital opening      | ig - ingesting gland |
| o - ovary            | po - pallial oviduct      | ro - renal oviduct   |
|                      | sr - receptaculum seminis |                      |

while the epithelium lining the gland itself is composed of large gland cells actively engaged in sperm ingestion. Oriented sperm cells were found attached to the walls of the duct to the ingesting gland, showing that the duct functions as a receptaculum seminis (sr).

The capsule gland resembles that of *Philbertia leufroyi boothi* in the complexity of its staining reactions. The bursa copulatrix (bc) is an incapacious, elongated structure with an epithelium comprising scattered mucous cells, ciliated cells and large gland cells.

## HERMAPHRODITIC SYSTEM

*Lora turricula*

In a number of specimens of this species both male and female systems were present in the same individual. It was thought best to deal with both the male and the female systems at the same time in order to facilitate discussion of the hermaphroditic condition.

The male system is quite normal and follows a pattern similar to that described for *Lora trevelliana* (Figure 14). The testis (t) shows no evidence of sexual transformation such as the presence of oocytes around the periphery, as found in *Crepidula fornicata* (COE, 1942). The vesicula

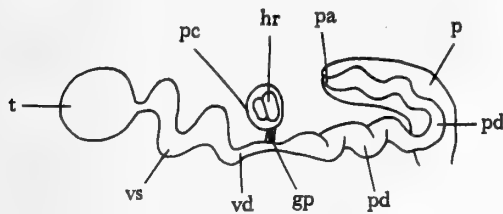


Figure 14  
*Lora turricula*

Diagrammatic Reconstruction from Sections of the Male System

gp - connective tissue remnant of gonopercardial duct  
hr - heart      p - penis      pa - opening of penis  
pc - pericardial wall      pd - duct from prostate      t - testis  
vd - vas deferens      vs - vesicula seminalis

seminalis (vs) is well developed and as in *Philbertia leufroyi boothi*, it is not ciliated but composed of gland cells, which are engaged in sperm ingestion near the testis. These cells rest on a basement membrane which is surrounded by a thin layer of connective tissue. The vas deferens (vd) is convoluted and made up of densely ciliated, cuboidal cells resting upon a thin basement membrane covered by a thin layer of muscle. There is a remnant of the gonopercardial duct (gp) attaching the vas deferens (vd) to the wall of the pericardium (pc).

There is no prostate gland nor opening into the mantle cavity. The ciliated epithelium of the vas deferens changes abruptly, near the posterior end of the kidney, to a mucoid epithelium containing small, ciliated cells wedged between large mucous cells. This type of glandular spermiduct (pd) continues to the tip of the penis as in *Lora trevelliana*.

A number of predominantly female specimens had large, round penes (Figure 15). In these specimens there was no trace of testis and only a small portion of the ovary (o) contained oocytes. The remainder of the last two visceral whorls was filled with mature, normal eggs. No evidence of a renal oviduct nor of a gonopercardial duct could be found. The thin gonadal oviduct (go) enters the albumen gland (al) directly, with no sphincter between it and the gland. It is composed of a non-glandular epithelium surrounded by a thin muscular layer.

The albumen gland (al) is ciliated and possesses sub-epithelial cells which are of two kinds. Those of the dorsal wall color deeply with Alcian blue, while those of the ventral wall stain with haemalum. The albumen gland opens into the capsule gland (cg) through a short, ciliated pallial oviduct (po); a thin layer of muscle surrounds the duct.

The ciliated ventral channel leads posteriorly from the bursa copulatrix (bc) along the ventral part of the capsule gland (cg) to join the pallial oviduct (po).

A short, ciliated duct connects the elongated receptaculum seminis (sr) to the pallial oviduct (po). The bulb is lined with a very thin ( $1.3\mu$ ), non-glandular epithelium. No evidence of sperm ingestion could be found, and indeed the thin epithelium does not seem to be of the type capable of ingesting sperm. The duct and receptaculum seminis are surrounded by a thin ( $4\mu$ ) muscle layer.

The well developed capsule gland (cg) is similar to that of *Lora trevelliana*, except that the three histological areas present in other species react differently to the same stain. The bursa copulatrix (bc) is very muscular with a large, ciliated lumen; gland cells are absent.

The male system, which is present in these same female specimens, consists of a normal penis (p) and glandular spermiduct (pd), which terminates in a sperm filled bulb near the albumen gland (al) of the female. Unoriented sperm was found along the spermiduct almost as far as the penis tip (pa).

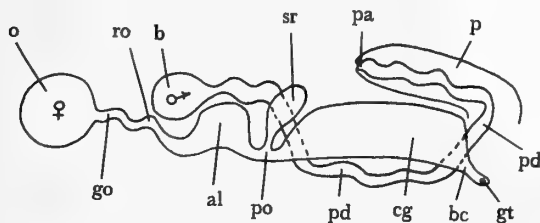


Figure 15

Diagrammatic Reconstruction from Sections of the Female System with the nearly complete Male System

al - albumen gland      b - bulb      bc - bursa copulatrix  
cg - capsule gland      go - gonadal oviduct      gt - genital opening  
o - ovary      p - penis      pa - opening of penis  
pd - duct from prostate      po - pallial oviduct      ro - renal oviduct  
sr - receptaculum seminis

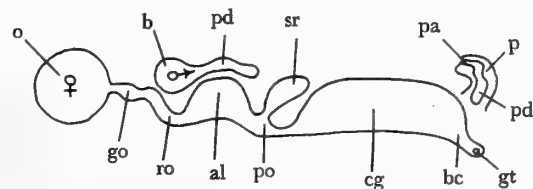


Figure 16

Diagrammatic Reconstruction from Sections of the Female System with Vestiges of the Male System

al - albumen gland      b - bulb      bc - bursa copulatrix  
cg - capsule gland      go - gonadal oviduct      gt - genital opening  
o - ovary      p - penis      pa - opening of penis  
pd - duct from prostate      po - pallial oviduct      ro - renal oviduct  
sr - receptaculum seminis

In one of the female specimens (Figure 16) the male system had atrophied so that only the terminal bulb (b), near the albumen gland (al) of the female, and a short portion of the glandular spermiduct remained. The penis was very reduced with no sperm present in any part of the male system.

## PEDAL GLANDS

Within the neogastropods the pedal glands are not entirely engaged in lubricating the foot during locomotion. They may undertake such diverse functions as moulding and attaching egg capsules or aiding in the boring of holes in the shell or hard exoskeleton of the prey.

The anterior pedal mucous glands open into a ciliated, sagittal canal in the turrids studied. In many cases these subepithelial glands do not react with Alcian blue nor give any indication of the presence of an acid mucopolysaccharide. In *Philbertia leufroyi* and *Mangelia attenuata* scattered mucous clusters occur mixed with darker, blue staining cells on both sides of the sagittal canal. In *Cenodagreutes aethus* and *C. coccyginus* the anterior pedal glands give three staining reactions. Some gland clusters stain with haemalum, some with eosin and haemalum, and a few others with Alcian blue.

"Sole glands" is a collective term applied by FRETTER & GRAHAM (1962) to include all the glands which pour secretions onto the surface of the sole, including goblet cells, which lie within the epithelium and subepithelial glands. In *Philbertia leufroyi boothi* a large mass of subepithelial glands fills much of the mesopodium. The gland cell clusters stain intensely with Alcian blue and open between the ciliated epithelial cells by long ducts onto the surface of the foot. In *Mangelia attenuata* the epithelium covering the sole is composed of eosinophilic cells interspaced by ciliated cells, mucous cells and subepithelial glands being absent. The posterior pedal mucous gland, which occurs in some rissoids and triphorids, is absent. The ventral pedal gland present in female muricids and buccinids and concerned with the final moulding and attachment of the egg capsules, is totally absent.

## DISCUSSION

The neogastropod reproductive system has been considered uniformly dioecious and it is, therefore, surprising to find that *Lora turricula* exhibits a form of hermaphroditism. In the mesogastropod genera, which exhibit true protandric consecutive sexuality, such as *Calyptraea*, *Crepidula* and *Crucibulum*, each individual functions as one sex when young (male) and as the opposite sex when

older. The histological basis of this type of sexuality depends upon the presence of an ambisexual gonad (COE, 1944). In addition, the male genital system is reconstructed into an oviduct, seminal receptaculum and vagina during the transition from the male phase to the female phase. This is not the case with *L. turricula*, since there is no ambisexual gonad, and the male and female reproductive systems are found together in the same individual. In *L. turricula* the gonads undergo a similar cycle to that described by YONGE (1962) for *Trichotropis cancellata*, where the gonads are undifferentiated during the transition from the male to the female phase. However, *L. turricula* differs from the above gastropods and from *T. borealis* (GRAHAM, 1956) in having two separate and complete reproductive systems present in the same individual, although the male system is no longer connected to the gonads and gradually atrophies during the change to the female phase, eventually leaving a separate, functional female system. This type of hermaphroditism is similar to that found in the pulmonates and opisthobranchs except that both sexual systems are not complete at the same time. It is conceivable that some specimens of *L. turricula* could act as functional hermaphrodites during the brief transitional phase when there is still sperm in the male duct and a well developed penis still present. The possibility of self-fertilization, as suggested by YONGE (1962) for *T. cancellata*, where the penis remains throughout the life of the female, seems remote in *L. turricula*.

In *Patella vulgata*, which exhibits alternative sexuality, ORTON, SOUTHWARD & DODD (1956) found, in a single population, that 90% of the small specimens, 16 - 25 mm in shell length, were males. Those with shells 40 mm long were male and female in equal numbers, while 60 - 70% of the larger animals, with shells 60 mm in length or longer, were female. Earlier ORTON (1919, 1928) suggested that the young population contained two kinds of male-phase individuals, true males and temporary males (protandric females). Due to the difficulty of locating *Lora turricula*, only a small number could be collected. This sample consisted of 15 individuals with an average shell length of 14.8 mm (Table 1). The sample can be broken into 3 males, 5 females, and 7 in various stages of the transitional phase. Contrary to what ORTON found, this small sample can not be broken into distinct sex phases based on shell size. The results from this sample seem to indicate that the population may consist of two sexual phases: a pure male phase and a temporary male phase (protandric hermaphrodite), later becoming female.

Populations of *Lora turricula* are probably restricted to small geographic areas by a number of complex factors, including specialized feeding habits and particle size of the substrate. Therefore, this form of hermaphroditism would be of direct importance to such insular populations

Table 1

Occurrence and Condition of the Reproductive Systems  
in 15 Specimens of *Lora turricula* Collected from the  
Clyde Sea Area, Scotland, During June, 1964.

No.	Shell size mm	Sex	Condition of reproductive system
1	9.7	♂	well developed male and female systems
2	12.5	♂	typical male, no trace of female system
3	13.0	♀	very reduced penis present
4	13.0	♀	well developed male and female systems, no testis present
5	13.5	♀	well developed female, no male system present
6	14.0	♀	well developed female, no male system present
7	14.5	♂	typical male, no trace of female system
8	14.5	♀	very reduced penis present
9	15.3	♂	typical male, no trace of female system
10	16.0	♀	well developed female, no male system present
11	16.6	♀	well developed male and female systems, no testis present
12	16.7	♀	very reduced penis present
13	17.3	♀	well developed female, no male system present
14	17.5	♀	well developed female, no male system present
15	18.8	♀	well developed male and female systems, no testis present

by assuring the presence of both males and females. Two causal factors have been indicated in the evolution of the hermaphroditic state, genetic change and environmental conditions (FRETTER & GRAHAM, 1964). Obviously, a genetic change has taken place in the isolated population studied and evidently hermaphroditism has not been selected against by the environmental conditions. Of course, a number of widely separated populations will have to be sampled in order to show that all populations of *L. turricula* exhibit hermaphroditism.

In some *Stenoglossa* FRETTER (1941) found that sperm ingestion, and in some species egg yolk ingestion, takes place in an ingesting gland located between the albumen and the capsule glands. The convoluted duct, which runs from the ingesting gland to the pallial oviduct, acts as a receptaculum seminis with oriented sperm attached along its walls. JOHANNSON (1957), from his work with *Nassarius pygmaea* and *N. incrassatus*, doubted that sperm ingestion occurred in all *Stenoglossa* which possess a gland in this same position. He also stated that it was not possible to rule out sperm ingestion in these species because of the simplicity of the epithelium lining the gland or because, at the time of sectioning, the gland cells did not contain ingested sperm. Sperm ingestion was not found in the turrid species *Mangelia attenuata* and *Lora trevelliana*. The histological nature of the epithelium and the condition of the sperm within the gland indicate that it is used for sperm storage as is the duct leading to the gland. This

case agrees with JOHANNSON's observations with both the gland and duct functioning as a receptaculum seminis.

In the turrids the ingesting gland and the receptaculum seminis are located in a proximal position which at first suggests a homology with the receptaculum of other gastropods, as postulated by FRETTER (1941) for the *Stenoglossa*. However, JOHANNSON (1957) has suggested that the ingesting gland corresponds to a proximal or inner bursa copulatrix and not a receptaculum. Although the turrids studied do not offer exception to FRETTER's theory, it would be misleading not to mention *Drupa nodulosa* (E. H. SMITH, in preparation) which supports JOHANNSON's theory since there is in this species both an ingesting gland and a separate receptaculum seminis. In addition, MARCUS (1962) has found that in some species of *Columbellidae* the pericardial cavity acts as a receptaculum seminis with no sperm ingestion, while in other species the long duct from the pallial oviduct may act as a receptaculum seminis or in some cases as an ingesting gland. From this information on the *Columbellidae*, it is apparent that the position of the ingesting gland varies in different families of the neogastropods and it is impossible to postulate a general homology for the gland that applies to the whole group.

In some *Stenoglossa* and *Toxoglossa* an "anterior sperm sac" is found. This bulb lies dorsally above the bursa copulatrix and opens into it through a duct or muscular opening. It occurs in the turrid *Philbertia leufroyi boothi*,

the terebrid *Hastula cinerea* (MARCUS, 1960), and in some Columbelloidea (MARCUS, 1962) and Muricidae (personal observation). This bulb usually contains vast amounts of oriented sperm cells which are attached to the wall or lie in rows that are unattached. In the case of the Columbelloidea it takes on the function of sperm ingesting and opens into the anteroventral portion of the bursa copulatrix. However, in *P. leufroyi boothi* there is no sperm ingestion and the "anterior sperm sac" acts as a receptaculum seminis in the absence of the usual one between the albumen and capsule glands.

In some species of *Stenoglossa* and *Toxoglossa* there is a duct leading from the prostate gland to the mantle cavity instead of the slit caused by the incomplete fusion of the two lobes of the prostate gland found in some muricids. In two turrid species, *Mangelia brachystoma* (ROBINSON, 1960) and *Cenodagreutes aethus*, a duct leads to the mantle cavity from the pallial portion of the vas deferens instead of from the prostate gland. FRETTER (1941) suggested that these well developed ducts which connect the spermiduct to the mantle cavity, may function in the removal of excess sperm though no definite evidence was presented. There is little doubt that the ducts in these two turrids are functional rather than being mere remnants of evolution, although there is no indication what the function could be.

The pedal glands, commonly found in the muricids and buccinids, are absent in the turrids, and yet the egg capsules, which are formed, are similar to those of the muricid *Trophon truncatus*. The laying of one egg capsule of *Cenodagreutes aethus* was observed, but owing to the small size of the snail, it was difficult to follow the entire event. The capsule seemed to be moved to the sole of the foot in the usual manner exhibited by the muricids and buccinids. With the absence of the ventral pedal gland the capsule gland may take over its function. Perhaps the more complex staining properties of the capsule gland in many of the turrids is an indication of the presence of added chemical substances that take the place of the secretion from the ventral pedal gland.

It is difficult to establish any phylogenetic relationships between the Turridae and other neogastropod families, or between the turrid species themselves. SCHILDER (1947) has placed the origin of the *Toxoglossa* in the upper Cretaceous or Paleocene, while POWELL (1942) believes that the origin of the Turridae took place at least in the early part of the Cretaceous, if not much earlier. The presence of free-swimming larvae (LEBOUR, 1937; THORSON, 1946) indicates a primitive condition of the Turridae, as compared to the *Stenoglossa*, where the tendency is to suppress free-living larvae. On the other hand, the complete fusion of the prostate gland in the male, the general lack of

gonopericardial connectives, and the occurrence of the hermaphroditic state, suggest a more advanced position. The paleontological record seems to indicate that the Turridae arose early from a common neogastropod stem. This early origin would allow time to develop specialized trends while retaining some of the more primitive features. The morphology of the turrid reproductive system is similar in many respects to that found in the Buccinidae and Muricidae, and does suggest parallel evolution of the *Stenoglossa*.

## SUMMARY

The functional morphology of the reproductive system in seven species of British turrids is described. One species, *Lora turricula*, is a protandrous hermaphrodite. The form of hermaphroditism described differs from that found in the mesogastropods in not having an ambisexual gonad and by possessing two separate reproductive systems, neither derived from the other, in the same individual; this latter characteristic is also present in the functional hermaphroditism of pulmonates and opisthobranchs. The possible cause and benefit of this type of reproduction is discussed. The function of the ingesting gland and receptaculum seminis is discussed and it is suggested that the homology between the ingesting gland of the *Stenoglossa* and the receptaculum seminis of other neogastropods can only be made in certain cases and can not be applied to the group as a whole. The pedal glands and the formation of the egg capsules in the turrids is described. It is concluded that, although no definite phylogenetic conclusions can be reached, the morphology of the turrid reproductive system suggests a parallel evolution to the *Stenoglossa*.

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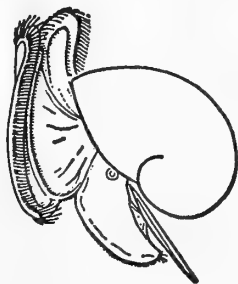
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# Enzymatic Defenses of Certain Snails Against Metal Ions

BY

LINDSAY R. WINKLER

AND

LOIS WONG CHI

College of the Desert, Palm Desert, California 92260  
and California State College Dominguez Hills, Gardena, California<sup>1</sup>

## INTRODUCTION

LITTLE STUDY HAS BEEN GIVEN to the defenses of snails against heavy metal ions even though it has long been known on a pragmatic basis that aquatic mollusks are highly sensitive to copper ions. Furthermore, copper ions have been used with some success against aquatic snails as a means of control. Since some snails appear to be more resistant to copper used as a control a study to assay possible defenses in one of these more highly resistant species should be of some general interest to snail physiology.

The shell is the first line of snail defense which protects the greater part of the otherwise poorly covered body from membrane-contact with the external environment. If the snail is an operculum-bearing prosobranch the ability to isolate itself from the surrounding environment is increased. Any ability to metabolize anaerobically further extends the period during which the snail can remain self-imprisoned during ionic crises in the surrounding environment and thus enhances the probability of ultimate survival.

During a previous study using *Oncomelania formosana* (PILSBRY & HIRASE, 1905) as the experimental animal it was determined (WINKLER & CHI, 1964) that certain cells free in the hemocoel picked up copper during chronic poisoning by very low levels of copper added to the environmental bath provided for these amphibious prosobranch snails. During the study it was further observed that snail squashes exposed to copper solution turned blue. Immersing live de-shelled snails in copper solutions similarly caused light blue areas to appear on the surface of the mantle, midbody and even on areas of the foot and digestive gland. The possibility that this represented a

defensive reaction of protective value to the snail served as the take-off point for the present study.

## MATERIALS AND METHODS

Snails used in this study were obtained from stock dishes of *Oncomelania formosana* (PILSBRY & HIRASE, 1905) reared and maintained in our laboratory as previously described (WAGNER & CHI, 1959). In order to remove the protection provided by the shell and operculum and to produce a degree of uniformity in the results all snails were de-shelled prior to use. The living snails were placed in 1% copper sulfate for the empirically chosen time periods of 3, 10, and 30 minutes, and 1, 3, 5 and 7 hours. This concentration was chosen to speed results since de-shelled snails do not live more than 24 hours. Immediately after exposure snails were killed and fixed in acetone at deep-freeze temperatures after which they were allowed to return to room temperature for storage. Snails destined for histochemical study were removed from acetone to two changes of tertiary butanol for a total of two hours, and then to benzene with one change for a total time of 15 minutes. From the last benzene the snails were transferred to about 5 ml of molten paraffin for 2½ hours, followed by conventional embedding procedures. This abbreviated procedure produced very adequate results with the small amount of tissue found in these snails. After serial sectioning and subsequent mounting on glass slides the sections were either left unstained for direct observation and chemical study of the blue colored objects, or were treated with the rubanic acid histochemical reagent for demonstration of micro amounts of copper using a modified method similar to that of UZMAN (1956). Eosin was used as counterstain. The carbonic anhydrase method of GOMORI (1952) employing cobalt was used on de-shelled acetone-fixed snails for confirmation of the presence of this enzyme. Snails were killed in subzero acetone, then

<sup>1</sup> This investigation was supported in part by grant No. AI-02705-07 from the National Institutes of Health. Part of this study was conducted at Immaculate Heart College, Los Angeles, California.

treated with the reagents, after which they were sectioned and mounted. Parallel procedures using copper were carried out for comparative purposes.

Quantitative determination of the rate of concentration of copper in the snail was made by exposing 6 de-shelled snails for each of the above mentioned time intervals. These were then rinsed and stored in cold acetone. After storage the acetone was removed with a minimum of  $\frac{1}{2}$  hour air evaporation. A modified form of the procedure of GUBLER *et al.* (1952) was used for spectrophotometric determination of copper. Individual snails, after being weighed to 4 decimal points on a Mettler H-15 balance, were placed in the courvette, after which 10 drops of 2N HCl were added and left to stand for 20 minutes. The solution was then made slightly alkaline with 4 drops of 1:3 ammonium hydroxide and the level was brought to a total of 3.2 ml with de-ionized water. After setting the 100% transmittance reading of the Spectronic 20 with this solution, 3 drops of diethyldithiocarbamate in 0.1% solution was added and the resultant reading was recorded from the photometer at  $440 \mu$ . If this transmittance reading was below 10 on the scale, an additional 3.2 ml of de-ionized distilled water was added and a second more accurate reading was obtained by halving the subsequent reading as indicated on the spectrophotometer. The copper present was then read in  $\gamma$  of copper from a curve previously prepared, using the same procedure on graded dilutions made from a standard copper solution. The addition of sodium pyrophosphate and citrate recommended by the original writer was omitted, since the control snails gave a uniform reading of under one  $\gamma$  of copper-equivalent of the combined iron and copper impurities. The results in  $\gamma$  per snail were finally converted to  $\gamma$  of copper per milligram of snail tissue and plotted against time (Figure 1a).

In order to determine the rate of copper concentration by carbonic anhydrase when the protective, living processes of the snail were removed, snails were killed by immersion in subzero acetone which did not deactivate the enzyme systems, and were then stored at deepfreeze temperatures for at least 12 hours. They were then exposed to the copper bath for the same time intervals as used in the previous experiments. After removal each was stored in acetone until it was quantitated by the procedure previously described (Figure 1b).

## RESULTS

The most significant observation noted on the sectioned material was the presence of large numbers of birds-egg-blue crystals which were effervescent when weak hydrochloric acid was introduced under the cover slip. This,

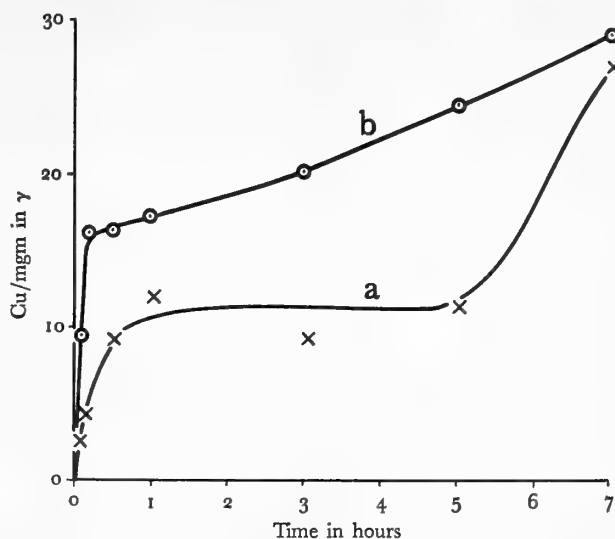


Figure 1

Curves showing rate of copper uptake by *Oncomelania formosana*. Curve a is that of de-shelled but living snails; b is the result when the snails were killed by storage in cold acetone – a procedure which but slightly reduced the enzyme activity. Each point represents averages for 6 and 4 snails on the two curves respectively. The copper levels of individual living snails of curve a were wider in range than those of the dead snails b, especially in the flat portion of the curve.

combined with their color, identified them as  $\text{CuCO}_3$ . These crystals were found covering the surfaces of the mantle, central body wall and, to a more limited extent, the foot and digestive gland. Furthermore, they also occurred in the peripheral tissues in specimens exposed for the longer time periods. Associated with these crystals were numbers of the free, spherical cells described in the previous paper; however, in these unstained sections many showed the same light blue color as the crystal formations. In addition, careful examination revealed the presence of one to many crystals contained in most of those showing the blue color. The GOMORI (1953) carbonic anhydrase activity test established these cells along with certain areas of the body wall, specifically those covering loose connective tissue, as the principal sites of activity of that enzyme.

The copper penetration observed in the rubenic acid-stained sections of snails exposed only briefly was predominantly in the midbody region with very little in the foot or in the digestive gland despite the very thin walls of the latter. Under limited exposure periods very few copper carbonate crystals were observed. Few of the protective cells (p-cells) were noted peripherally but these increased in number with time as did also the formation of copper carbonate.

The chief loci of copper carbonate as well as of clumped p-cells were in loose connective tissue, usually immediately below the thin outer walls. It was difficult to separate the crystal formation from the clumps of these p-cells. Particularly was this true under the high sensitivity of the rubeanic acid test which tended to blur the clumps of cells. Unstained slides were distinctly superior under these conditions.

As time of exposure progressed concentration rose in the peripheral connective tissue of the mid-body area. Only in exposures above 3 hours was there considerable invasion in other than peripheral tissues of the foot and digestive gland.

The extent of the immobilization of soluble copper and its concentration into insoluble copper carbonate was studied using snails killed in subzero acetone in order to retain enzyme activity. When the amount of copper fixed in each snail was quantitated, averaged and graphed (Figure 1b) it was observed to rise sharply to  $16\gamma$  per mgm in those with 10 minutes exposure. Thereafter the curve sharply leveled, then continued its rise at a gentler slope terminating at  $27\gamma$  in snails of 7 hour exposure. When the living processes were superimposed by not killing the snails till after copper exposure (Figure 1a), the curve rose considerably less precipitously to a little over  $10\gamma$  of copper per mgm during the first half hour. This was followed by  $4\frac{1}{2}$  hours in which little change was observed but in which considerably more variability occurred between individuals of the same exposure increment. The resistance of the living process appeared to break down somewhere between 5 and 7 hours, allowing a rapid rise to approximately the same level as that of the snails exposed after having been killed.

## DISCUSSION AND CONCLUSIONS

The observed formation of insoluble  $\text{CuCO}_3$  seems to be a part of the snails' defenses rather than only a byproduct of shell formation since the centers of carbonic anhydrase activity revealed by the Gomori test were principally the p-cells which were widely spread throughout the snail body. Copper used in place of cobalt in a parallel procedure also revealed one factor that appears in distinct contrast between the two ions. While cobalt localized itself in the sites of carbonic acid activity with very little attaching to the tissues, copper attached itself extensively on all tissues. This is not the result of greater sensitivity of the test as the same "sulfide procedure" for detecting the presence of cobalt was used for the copper in this procedure. One exception to the above statement was the strong affinity for the primary reproductive organ evident

by heavy differential staining of the latter tissue when using the cobalt procedure.

The p-cells exist in various sizes and may be observed thus in the various clumps where they occur. When iron was substituted for the copper, the p-cells were not masked by staining of surrounding areas. It was then possible to locate what appeared to be the sites of origin of the p-cells in pockets of the loose connective tissue. In these pockets large numbers of miniature p-cells of homogeneous sizes were observed. These were interpreted to be developing p-cells.

When iron or calcium was substituted for copper, the results were less definitive. In both cases the cells gave the stain characteristic of the ion involved, but crystal formation did not occur. Calcium was not noted bound to the tissues, but iron, as was the case also with copper, was observed extensively on the surface of all the tissues.

The curves which compare the concentrations of copper in the snail emphasize the modifying influence of the living process and the effectiveness of the active transport system at keeping the system relatively free of copper even under the extremes of trauma and high copper concentration. What does find its way into the hemolymph of the snail is picked up by the p-cells.

The abrupt leveling off of the rise in snails without the living process at  $16\gamma$  (Figure 1b) probably results from depletion of carbon dioxide from the environment. The remaining even slope may represent the diffusion of carbon dioxide into the solution from the surrounding environment, perhaps augmented as the result of the binding of copper by the dead tissues.

The less steep rise during the first hour apparent in the curve of the living snails (Figure 1a) apparently represents the formation of crystals on the surface and in the peripheral p-cells. Copper penetration then remains static until sometime after the 5<sup>th</sup> hour. The rise after the 5<sup>th</sup> hour would logically seem to be the result of the internal protein binding or the depositing of copper crystals in areas previously unavailable because of the resistance of the living process.

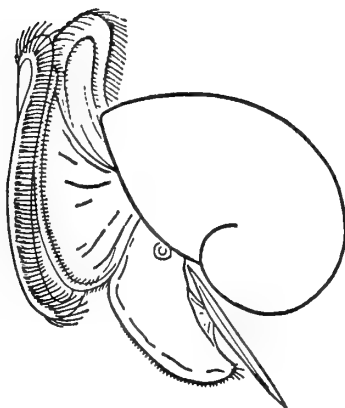
The inspection of the graphs offers little comfort to molluscicides. The resistance here observed against these high concentrations of copper used on snails having already been deprived of their first line of defense would seem to indicate their ability to withstand relatively long sieges of the lower concentrations normally used as molluscicides by snails possessing all their faculties.

It is not known how far the process of crystal formation can actually protect these snails from death but the combination of an impermeable shell with functional operculum, a considerable anaerobic capability and the enzymatic

deactivation of copper seem to make this prosobranch snail relatively immune to ordinary acute ionic attacks which might be lethal to less highly favored snails.

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# The Radulae of Nine Species of Mitridae

(Mollusca : Gastropoda)

BY

JEAN M. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 19; 9 Text figures)

## INTRODUCTION

IN RECENT YEARS more and more attention is being given to the study of mitrid radulae. CERNOHORSKY (1966) has provided the largest and most comprehensive recent work, covering about 50 species; even so, the total of known, accurately identified mitrid radulae still stands at only around 100 species. Helpful as this is to workers in this group, we have to admit that it is only a beginning, in a family comprised possibly of some 500 to 600 Recent species. It has been seen that our new knowledge of many of the radulae is negating the earlier generic and subgeneric placements of certain species whose taxonomic assignments were based on shell morphology alone. Consequently, it is evident that at some future date the Mitridae will need to be thoroughly revised, with totally new concepts of the genera and subgenera different from those we know now. However, with such a slow trickle of information as is presently becoming available, it would seem to me premature to attempt to make such drastic changes at this time, for the radula patterns of approximately 85% of the species are still unknown. It may well be that the radula will prove to be of greater (or, possibly, lesser!) importance than is accepted today. Certainly the morphological characters can not be totally ignored, for it is seldom indeed that live-collected material becomes available for radula study and it may be many years before a relatively complete knowledge of all the species can be obtained. It seems to me that the conchologists must, therefore, continue to arrange their collections in groupings of "look-alike" shells; i. e., as nearly as possible in the recognized genera and subgenera, however arbitrary and artificial a system this may be according to the radular characters.

A case in point is *Strigatella columbellaeformis* (KIENER, 1839). The morphological features of this species fit the description of the typical *Strigatella* so well as to be almost amusingly "supertypical." Its features seem an exaggerated version of SWAINSON's description: "Size

very small; spire thick, obtuse; outer lip thickened, and often reflected in the middle; aperture smooth." CERNOHORSKY (1966a) has shown that the radula pattern of this species renders its placement in *Strigatella* incorrect, and that it should be assigned more correctly to *Mitra* s. s. It comes down, then, to the very practical consideration of how museum curators and private collectors shall curate their collections, with such apparently "typical" forms really belonging, according to their radular characters, alongside morphologically completely dissimilar forms. This problem is negligible in small collections, but with a collection of Mitridae numbering into the hundreds of species and thousands of specimens it becomes important to have the similar species grouped together.

If a student were, for example, to bring to a large museum for identification a typical small, drab, brown strigatelliform shell, the most logical place to seek its identity would be among the Strigatellas. Unless the curator happened to be a specialist in Mitridae he would be more than likely to overlook a comparison of the unknown form with "*Mitra*" *columbellaeformis* which had been placed, in accordance with its radular pattern, together with such typical mitrid forms as the showy, red-spotted, elongate and pointed *Mitra mitra* (LINNAEUS, 1758), and not among the Strigatellas. Only by a slow, painstaking comparison with every species in the *Mitra* collection could an identification be made under this system, whereas the smaller sub-grouping of all shells having *Strigatella* characters would normally make it easy to locate the name within a relatively short time.

It seems that the whole question may already have resolved into an argument between the supporters of the shell-morphology school of thought and the champions of the radula pattern, in somewhat the same way *Cypraea* collectors have their "lumpers and splitters" — though for slightly different reasons. Both may be correct in their different views; who can say, at this early stage, which has

the ultimate single answer? I believe we must continue to strive for the solution by continuing to study additional radula material, but not to make the final decision until vastly larger numbers of species have been studied. At the present time only about 15% of the mitrid radulae are known; it would seem to me that nearer 90% should be known before the radical revision can be undertaken that will decide the question once and for all.

To add to our slowly increasing series of radula studies in Mitridae, I offer here illustrations of the shells and radulae of nine species of *Mitra* and *Vexillum*. Seven of these are either previously unrecorded or at least not specifically verified through references to adequate illustrations. Two radulae (*Mitra idae* MELVILL, 1893 and *Strigatella tristis* (BRODERIP, 1836)) have recently been figured by CERNOHORSKY (1966) but without accompanying illustrations of the shells. My work corroborates his findings on these two species.

## MATERIAL AND METHODS

The radula preparations were made by me during the past three years, whenever appropriate fresh material became available: the radulae were extracted through the use of potassium hydroxide solutions, dehydrated in alcohol series, stained with Acetocarmine and mounted in Euparal on glass slides. The text figures were prepared for publication by Mrs. Emily Reid.

## OBSERVATIONS

Study of these radulae resulted in no unexpected changes of assignment of the species to their respective genera, with the exception of *Mitra* (*Cancilla*) *verrucosa* (REEVE, 1845) (see Plate 19, Figure 7). CERNOHORSKY (1965) tentatively placed this species in *Vexillum*, but while its morphology does present a conflicting set of characters, its placement in *Cancilla* is justified on morphological grounds as well as radula characters. It is a puzzling species, for the reason that it bears spiral rows of prominent nodules throughout; from one viewpoint it could be said that the nodules are aligned in axial rows (making it eligible for assignment to *Vexillum*), whereas from another viewpoint the nodules could be considered to be arranged spirally in concentric rows. After a good deal of study when I first added this species to my collection several years ago, I concluded that the axial alignment was more or less accidental, and decided to place it among the *Cancillas* on the basis of the concentricity of the rows of nodules; the radula now supports this decision. The nodules are an atypical feature of most species of *Cancilla*, but the con-

centric sculpture is a character that places it without question in that subgenus.

1. *Mitra idae* MELVILL, 1893  
(Plate 19, Figure 1)

**Animal:** Foot, body, siphon and tentacles pure porcelain-white. Eyes situated at base of tentacles. Sexes separate.



Figure 1

Half-Row of Radula of *Mitra idae* MELVILL

Specimen collected in 50 feet off Point Loma, San Diego, California by Glen Bickford

2. *Mitra belcheri* HINDS, 1832  
(Plate 19, Figure 2)

**Animal:** Unknown (received in dried-out condition).

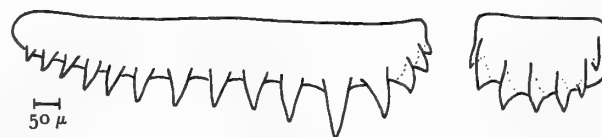


Figure 2

Half-Row of Radula of *Mitra belcheri* HINDS

Specimen trawled in deep water off Guaymas, West Mexico by shrimp fishermen

3. *Mitra zaca* STRONG, HANNA & HERTLEIN, 1933  
(Plate 19, Figure 3)

**Animal:** Unknown (received in dried-out condition).



Figure 3

Half-Row of Radula of *Mitra zaca* STRONG, HANNA & HERTLEIN

Specimen trawled in deep water off Guaymas, West Mexico by shrimp fishermen

4. *Mitra terebralis* LAMARCK, 1811  
(Plate 19, Figure 4)

(synonyms: *Mitra incompta* LIGHTFOOT, 1786; *M. tessellata* MARTYN, 1786)

**Animal:** Top of foot mottled with tan. Base of foot cream, tinged with reddish brown. Tentacles pale tan tipped with

white. Siphon banded proximally from the tip with white, brown and light tan, each color grading into the next (C. S. Weaver, pers. comm.). Length 80.9 mm, width 20.8 mm. leg. C. S. Weaver, Oahu, Hawaii, 1961.



Figure 4  
Half-Row of Radula of *Mitra terebralis* LAMARCK  
Specimen described above.

5. *Mitra aurora* DOHRN, 1860  
(Plate 19, Figure 5)

Animal: Unknown.



Figure 5  
Half-Row of Radula of *Mitra aurora* DOHRN  
Specimen collected in 15 feet of water, in sand under dead coral  
off Barber's Point, Oahu, Hawaii; leg. C. S. Weaver

6. *Strigatella tristis* (BRODERIP, 1836)  
(Plate 19, Figure 6)

Animal: Foot, body, siphon and tentacles creamy-beige;  
eyes situated at base of tentacles.



Figure 6  
Half-Row of Radula of *Strigatella tristis* (BRODERIP)  
Specimen collected at Puertecitos, Baja California, Mexico;  
leg. Fay Wolfson

7. *Mitra (Cancilla) verrucosa* REEVE, 1845  
(Plate 19, Figure 7)

Animal: Unknown.



Figure 7  
Radular Row of *Mitra (Cancilla) verrucosa* REEVE  
Specimen collected at Mauban, Quezon, Philippines;  
F. G. Dayrit, don.

8. *Mitra (Cancilla) hindsii* REEVE, 1844  
(Plate 19, Figure 8)

Animal: Unknown.



Figure 8  
Half-Row of Radula of *Mitra (Cancilla) hindsii* REEVE  
Specimen collected in 20 fathoms off Baco-chibampo Bay,  
West Mexico. leg. Gale G. Sphon, Jr.

9. *Vexillum taeniatum* (LAMARCK, 1811)  
(Plate 19, Figure 9)

Animal: Unknown.

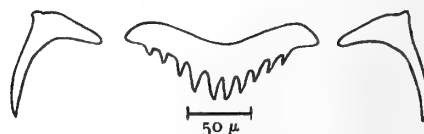


Figure 9  
Radular Row of *Vexillum taeniatum* (LAMARCK)  
Specimen collected by A. Jennings at Akuilau Island, Fiji  
and kept in his aquarium until it died. He then generously sent it  
to me intact so that I could obtain the radula without damaging the  
shell; the animal had completely decomposed. This is the  
specimen figured on Plate 19, Figure 9.  
Length 50.9 mm, width 10.9 mm.

### Explanation of Plate 19

Figure 1: *Mitra idae* MELVILL, 1893 ( $\times 1\frac{1}{4}$ )

Figure 2: *Mitra belcheri* HINDS, 1832 ( $\times \frac{1}{2}$ )

Figure 3: *Mitra zaca* STRONG, HANNA & HERTLEIN, 1933 ( $\times \frac{1}{2}$ )

Figure 4: *Mitra terebralis* LAMARCK, 1811 ( $\times \frac{3}{2}$ )

Figure 9: *Vexillum taeniatum* (LAMARCK, 1811) ( $\times \frac{7}{8}$ )

Figure 5: *Mitra aurora* DOHRN, 1860 ( $\times 2$ )

Figure 6: *Strigatella tristis* (BRODERIP, 1836) ( $\times 2$ )

Figure 7: *Mitra (Cancilla) verrucosa* REEVE, 1845 ( $\times 3$ )

Figure 8: *Mitra (Cancilla) hindsii* REEVE, 1844 ( $\times 2\frac{1}{2}$ )



Figure 1



Figure 2



Figure 3

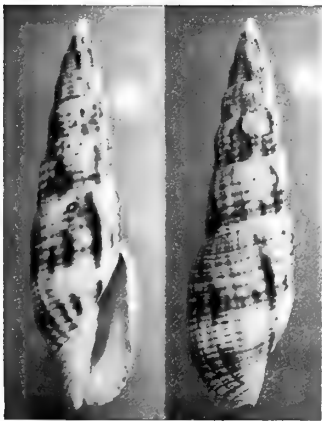


Figure 4



Figure 5



Figure 6

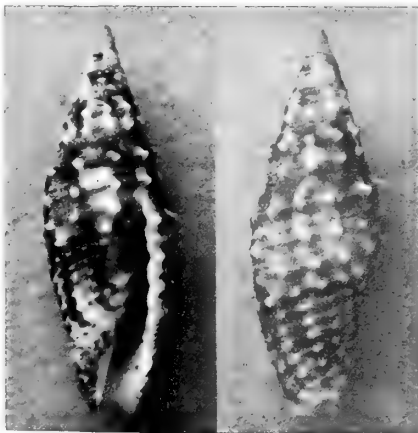


Figure 7

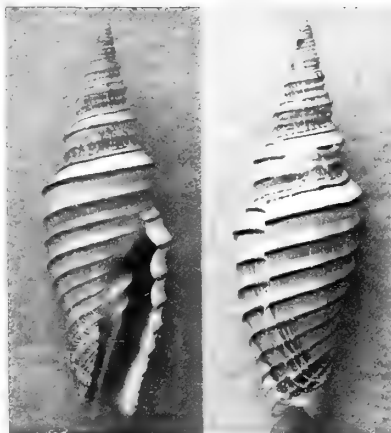


Figure 8

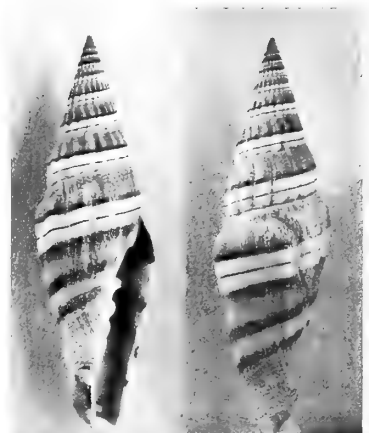


Figure 9



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# A New Species of *Marginella* from the Coast of Brazil

BY

JEAN-JACQUES VAN MOL

Laboratoire de Zoologie Systématique, Université Libre de Bruxelles, Belgique

AND

BERNARD TURSCH

Laboratoire de Chimie Organique, E. P., Université Libre de Bruxelles, Belgique

(1 Text figure)

THIS IS THE SECOND in a projected series of papers describing new species of mollusks from Brazil, the first having appeared in Volume 7, No. 1 of *The Veliger* (TURSCH & PIERRET, 1964).

## CTENOBRANCHIATA

### VOLUTACEA

#### MARGINELLIDAE

*Marginella* LAMARCK, 1799

*Marginella (Prunum) matthewsi* VAN MOL & TURSCH  
spec. nov.

(Figure 1)

**Description:** Shell large for the family, rather thin but solid, light orange-brown with numerous fine yellowish spiral bands. Surface glossy. Whorls about 5, including teleoconch. Aperture ivory-white, long and rather narrow, extending the entire length of the shell. Four prominent columellar plications, the uppermost being separated from a long glazed parietal callus by a well-defined sulcus. The parietal callus is thickened at the posterior extremity of the aperture. Outer lip thickened, showing on its inner side a row of numerous rather indistinct denticulations on all its length. Spire flat, nuclear whorls apparent, suture distinct as a white line.

#### Dimensions:

	(in millimeters)		Number of Whorls
	Length	Width	
Holotype	39.4	23.8	4.5
Paratype A	45.2	27.2	5
Paratype B	40.2	24.0	4.5

**Type locality:** The holotype and paratype B were obtained from the stomachs of fishes locally known under the name of "pacamão," caught off Fortaleza, State of Ceará,

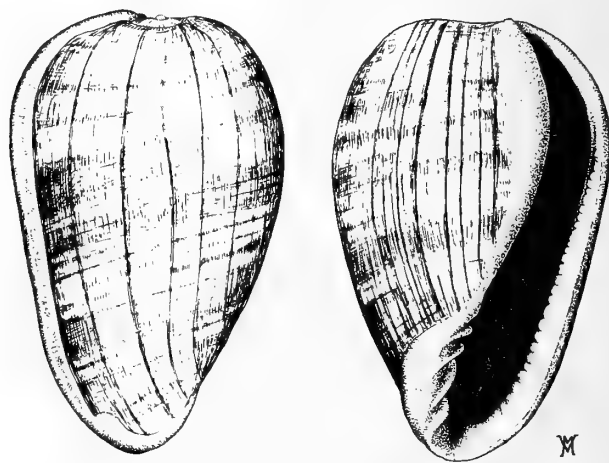


Figure 1

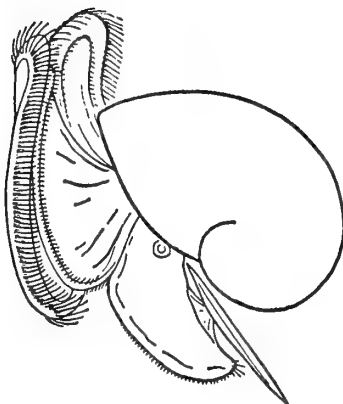
Brazil, in about 20 fathoms. Nature of the bottom: numerous coral heads on sand. Paratype A is from Acaraú, State of Ceará, also *ex pisce*.

**Repositories:** Holotype, Stanford University Paleo. Type Collection no. 9856. Paratype A, in Tursch collection. Paratype B in American Museum of Natural History, New York.

**Discussion:** This species is somewhat similar to the well-known *Marginella bullata* LINNAEUS, 1758, from which it is easily separated by the following characters:

	<i>Marginella bullata</i>	<i>Marginella matthewsi</i>
Colour:	rosy-gray	orange-brown
Spire:	covered by glassy layer	apparent, suture distinct
Parietal callus:	absent	present
Interior of outer lip:	nearly smooth	numerous small teeth
Dorsal side of	orange-brown,	creamy, subcarinated,
labial thickening:	rounded profile	characteristically expanded at anterior end

To our knowledge, *Marginella matthewsi* is not sympatric with *M. bullata*, whose distribution center is in the State of Bahia. This new species is dedicated to Mr. Henry Matthews, British Vice-Consul in Fortaleza, whose kind and competent help greatly facilitated our collecting in Ceará.



# The Rediscovery of *Erosaria menkeana* (DESHAYES, 1863)

(Mollusca : Gastropoda)

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plate 20)

CONSIDERABLE REFERENCE has already been made in the literature to a cowrie species that apparently remains clouded in synonymy. It is likely that earlier authors lacked access to an obviously rare species for comparison. I am certain that the shells illustrated in this paper definitely appear to be unrelated to one another, and should now be given adequate consideration, with one of them, *Erosaria menkeana* (DESHAYES, 1863) being regarded as a valid species once more.

The genus *Erosaria* TROSCHEL, 1863, with which I associate this species, usually has a characteristic morphology, a broad, flattened shell, with colored spotting. Therefore, shells of *Erosaria* follow this general description: shell ovate to sub-pyriform, not umbilicate, usually thickly margined, heavily calloused; tuberculate or smooth, with coarse teeth that do not cross the base and do not reach the margins; usually flattened, spreading; terminals only slightly produced, or in some cases not at all; shell may be marginally spotted, spotted over all, blotched, obscurely banded, or peripherally ringed with color. It would seem *E. menkeana* agrees well with this generic description.

*Erosaria (Erosaria) menkeana* (DESHAYES, 1863)

(Plate 20, Figure 1, 1a)

Conch. Ile Réunion, Annexe E (Moll.): 139; plt. 13, figs. 21 - 22

Syn.: *Cypraea modesta* (OWEN) SOWERBY (2<sup>ND</sup>), 1870

Thesaurus Conchyl. 4: 11; plt. 322, figs. 333 - 334

**Locality:** Mauritius (Long. 20° 18' S; Lat. 57° 36' E).

**Shell Measurements:** Length 20.0 mm, width 13.0 mm, height 9.0 mm; labial teeth 16; columellar teeth 13.

This species is clearly and unmistakably illustrated in SOWERBY (2<sup>ND</sup>) (1870). With the discovery of a live-collected specimen, it seems to me this heretofore obscure species should be accepted as valid. Toward this end I offer the following illustrations and redescription.

Shell small for the genus, elongately ovate, broad, flattened, solid, strong, thickly formed; dorsum transversely rounded, laterally flattened centrally due to two abrupt contour angles that divide the shell into three equal parts; base and outer lip convex from margins to aperture; terminal strongly produced abapically, less so adapically; aperture straight, narrow; both columella and fossula dentate; fossula shallow, nearly obsolete; teeth large, strong, well defined on both outer lip and base, extending halfway to margins; margins thick, rounded, indistinct, barely angularly shouldered above; primary shell color milk-white; dorsum glossy, thickly flecked with numerous very fine chestnut-brown spots, becoming fewer in number and minutely larger on margins, part of base and outer lip; very faintly quadrimaculate at terminals; a narrow portion of base, outer lip, teeth, and interstices white.

This shell was sent to me for identification by an Australian correspondent. The locality given was Mauritius in the Indian Ocean; at the present time this locality remains unverified. In making a search of the literature, I found that SOWERBY (2<sup>ND</sup>) (1870, plt. 322, figs. 333, 334) provided drawings almost identical with the shell at hand. With the aid of these hand-colored illustrations one has little difficulty in identifying this shell as a species long thought to be synonymous with *Bistolida owenii owenii* (SOWERBY [1<sup>ST</sup>], 1837); SOWERBY (2<sup>ND</sup>) (1870, plt. 323, figs. 366 - 371); this paper (Plate 20, Figure 2). It may be of interest to note that REEVE (1846) and KIENER (1845) do not list the latter species even though it had been almost ten years since SOWERBY (2<sup>ND</sup>) described it.

In the text SOWERBY (2<sup>ND</sup>) (1870, p. 11, species 27) discussed the species under consideration under the name *Cypraea menkeana* OWEN (= *Cypraea menkeana* DESHAYES, 1863). When comparing this shell with *Bistolida owenii owenii* he said, "... it does not well agree." He then stated further, "... the shell which Mr. Hugh Owen

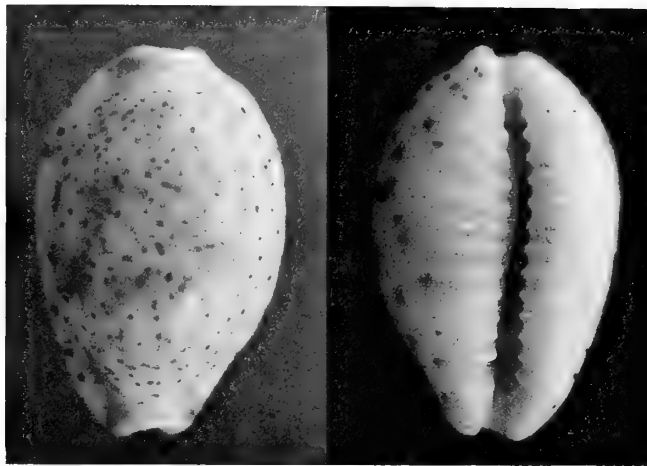
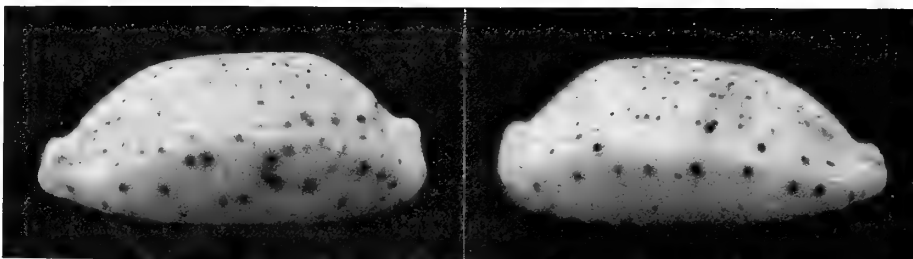


Figure 1  
*Erosaria menkeana* (DESHAYES, 1863) ( $\times 2\frac{1}{2}$ )



Left Side

Right Side

Figure 1 a  
*Erosaria menkeana* (DESHAYES, 1863) ( $\times 2\frac{1}{2}$ )

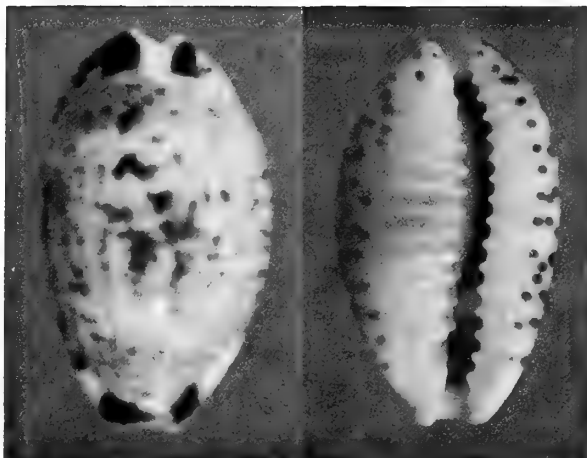


Figure 2  
*Bistolida owenii owenii*  
(SOWERBY, 1837) ( $\times 3\frac{1}{4}$ )

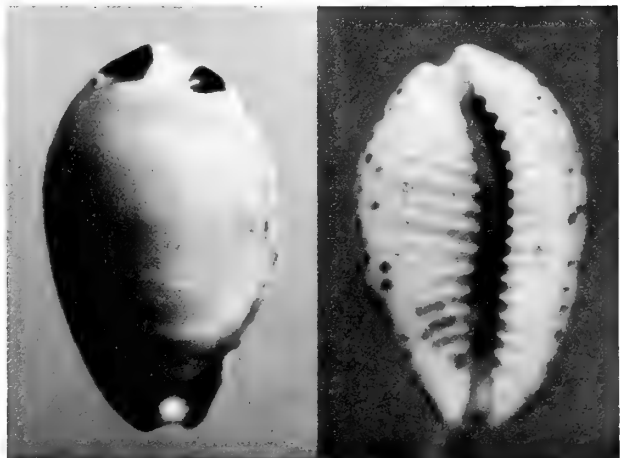


Figure 3  
*Bistolida owenii vasta*  
(SCHILDER & SCHILDER, 1938) ( $\times 2\frac{1}{2}$ )



names *modesta* ... seems to fulfill all the conditions to identify it with *menkeana*."

As I compared this recently collected shell with the SOWERBY (2<sup>nd</sup>) drawings of "*Cypraea menkeana*" it became increasingly apparent that the two are almost identical, almost as if the original drawings were made from this specimen. It is now evident that this specimen disproves the uniqueness of the SOWERBY shell, and supports the validity of this species.

I have compared the shell with *Bistolida owenii owenii* and with the allopatric form *B. owenii vasta* (SCHILDER & SCHILDER, 1938) (see Plate 20, Figure 3), the former from Mauritius and the latter from Durban, South Africa. The morphological distinction between them seems complete, with *menkeana* even probably belonging in a different genus, *Erosaria*, to which I have assigned it.

SOWERBY (2<sup>nd</sup>) illustrated "*Cypraea menkeana*" twice: on plate 327, figure 512, a shell from Borneo (a questionable locality since the species involved in this discussion are now known to occur only in the western Indian Ocean), and plate 322, figures 333, 334 (ventral and dorsal aspects), a shell from Île Réunion, located approximately 200 miles west of Mauritius. However, these two figures clearly seem to illustrate different species, figure 512 depicting *Bistolida owenii owenii* and only figures 333 and 334 in fact representing *Erosaria menkeana*.

WEINKAUFF (1881) recognized the species in question, using the name "*Cypraea menkeana*, non Sowerby," to identify it. He illustrated the species on plate 13 (figures 9 and 12). It is interesting to note that neither of WEINKAUFF's drawings agree with one another in outline of form, although it would appear that an effort had been made to copy Sowerby's figures. Ignoring the poor outline the ventral aspect agrees well, but the dorsal view is incomplete, showing what appears to be a decorticated upper shell surface.

HIDALGO (1906) mentioned this species as a synonym, and listed it as a sixth variety of "*Cypraea owenii* GRAY" [sic]. He interpreted Sowerby's use of names for the species as "*Cypraea menkeana* var. *modesta*."

TRYON (1885) said, "From a careful comparison of specimens of this shell [*Bistolida owenii owenii*] with those of *C. menkeana* Desh. (Pl. 4, figs. 69, 70, from Deshayes; Pl. 4, fig. 58; Pl. 5, fig. 73, from Sowerby), both of which were received from Mr. Sowerby, I do not hesitate to place the latter as a synonym. The only noticeable difference is in the marginal dots, which in *menkeana* sometimes run together giving a solid brown appearance. Specimens of *C. owenii* [sic] received from Mr. J. F. Bailey, of Melbourne, Victoria (Australia), are rather elongate, yellowish, and have a faded appearance, but decorticated shells are fawn-colored."

In an assessment of TRYON's opinion in regard to these shells it is important to bear in mind that DESHAYES' type specimen, or one similar to it, and SOWERBY's shell used for his Thesaurus illustrations conceivably could be in color and morphological agreement with each other. Even though TRYON's illustrations of *Bistolida owenii owenii* are poor and hardly representative of the species, it is fairly easy to note a difference between the species as he separated them for purposes of comparison.

Most recently *Erosaria menkeana* is listed in SCHILDER & SCHILDER (1938, p. 166, species 104A), and again in SCHILDER (1941, p. 99) as *Bistolida (Derstolida) menkeana*, citing it as a synonym of *B. (D.) owenii owenii*. However, with this rare cowrie species now available for study, it seems likely the taxon will stand as a valid species.

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# Notes on Cephalopods from Northern California

BY

ROBERT R. TALMADGE

Field Associate, Department of Invertebrate Zoology,  
California Academy of Sciences, San Francisco, California 94118, and Eureka, California

IN 1912 S. STILLMAN BERRY published a paper on the cephalopods of western North America, a painstaking and comprehensive study, long out of print, but still the only accurate account available today, covering this interesting class of mollusks in the designated area. ROBSON's (1929-1931) two part monographic work was limited to the Octopoda, and PICKFORD (1964) presented a detailed study of a single polymorphic species of octopod. There have been a number of taxonomic and distributional notes published, but as far as I could learn, there has been no detailed study covering any one portion of the California coast.

The following brief notes are presented not as a taxonomic discussion, but rather to bring together new and additional information on the basic ecology, distribution and, to some extent, the physical characteristics of several cephalopods found in two degrees of Latitude on the extreme northern coast of California (Lat.  $39^{\circ} 30' N$  to  $41^{\circ} 30' N$ ). All of the data are based upon specimens deposited in the collection of the California Academy of Sciences or in my own collection. The specimens for the most part were obtained by the commercial dragboat fleet operating out of Humboldt Bay, California.

At this time I wish to express my appreciation to the men who have so willingly brought me the specimens for many of the present records. I also wish to express my appreciation to the staff of the California Academy of Sciences for assistance given me while I was at the Academy and for the permission granted to include data from the Academy Collection.

## COMMERCIAL FISHERIES

There are no commercial fisheries as such for either squid or octopus on Humboldt Bay. I have noted squid, *Loligo opalescens* BERRY, in one of the local fish markets, but learned that these had been shipped from Monterey, California. Squid used for bait by the crab fishermen is brought from Monterey and recently also from Japan. A few octopus are brought ashore by the fishermen for display in a local commercial aquarium, for specimens, or as an epicurean item. Although a few squids have been

caught off this coast, the numbers are small and not sufficient to support a bait fishery.

## DAMAGED AND DISTORTED SPECIMENS

The often torn or mangled condition of many benthic cephalopods may be easily understood if a person observes the operation of capture. All cephalopods have soft bodies, but many of the benthic species have a body so soft that the tissues are gelatin-like in texture. This is possibly useful to the animal as it moves voluntarily from layer to layer in the depths. It would allow the pressure to equalize both within and without the animal tissues. However, when the cephalopod is caught in the fishing net, mixed in with perhaps several tons of fish, and then rapidly brought to the surface, it is difficult or probably impossible for the animal to equalize the internal pressure, and a nearly explosive decompression occurs in the cephalopods as it does in the fish brought from the same depths. The ultra-soft tissues then are torn easily by the net, by projections on deck, or among the fishes themselves.

Distortion occurs from such pressure release as well as from several other factors. In order to keep this distortion to a minimum, special jars of preservatives were placed on a number of the Otter Trawlers so that all of the specimens would be field-preserved in a similar preserving medium. This was also necessary in order to harden the gelatin-like tissue of the deeper benthic species so that they would be available for later study.

## COLORATION

Reference to the coloration of cephalopods is, at best, rather uncertain. The species not only are able to change color at will, but vary considerably from life to death, and from death to a preserved state. The preservatives themselves may affect coloration, alcohol acting as a bleaching agent, to name one example. Therefore, the preservatives furnished to the vessels actually were a mixture, and every effort was made to secure any specimens brought in within a week in order to obtain a better understanding of the coloration. In addition, comparison

with living animals was made whenever possible. One important factor was noted: in life the animals are translucent or nearly transparent, with the colored chromatophores standing out in a starkly contrasting manner; at death this translucent body became opaque and when preserved turned a dead white. In some species the rusty browns became darker and in others lighter. But most very old specimens examined were a dead opaque white.

### SPECIES

At the present time there are 10 species of cephalopods in the collections of the California Academy of Sciences and in the Talmadge Collection which were obtained from off this region in northern California. Since many species are pelagic, it is quite possible that additional species will be found in time. The following is a list of the species represented in the collections mentioned.

#### *Octopus dofleini martini* PICKFORD, 1964

I use this taxon, but the species is also known as *Octopus punctatus* GABB, 1862; *O. hongkongensis* auct., non HOYLE, 1885; *O. apollyon* auct., et (BERRY, s. l.), non (BERRY, s. s.), 1912. As PICKFORD has probably worked with more specimens of this, the largest known species, than any other worker, I follow her diagnosis. BERRY (1912) was perhaps the first worker to hint at an eastern : western Pacific separation and proposed the name *O. apollyon* for the western Pacific population, but restricted the type to an Alaskan specimen. PICKFORD agreed with BERRY and designated *O. dofleini apollyon* BERRY as the Alaskan subspecies. It is evident that BERRY realized the situation, but lacked sufficient material to complete his diagnosis.

In northern California the species is found from the deep intertidal down to around 40 fathoms, usually in a hard mud or rocky substratum. This is one of the "hard" bodied species and sets firmly in preservatives. In life the species is usually tan or grey, darker on the dorsum, and when placed in preservatives will often turn to a purplish brown. Although it is reported to attain great size, (BERRY, 1912, quoting DALL as stating that the species will reach a spread of 28 feet at Sitka) I have never seen one that would exceed 18 feet when spread on a dock.

#### *Octopus californicus* (BERRY, 1911)

The "Anna W", one of the larger dragboats on Humboldt Bay, has brought me several specimens taken north of Eureka in less than 100 fathoms on a sandy bottom. The captain noted that the coarse nodes present on preserved specimens were not noticeable in life, but became quite apparent when the animal was placed in preservatives. The coloration is a dark rich reddish brown, and becomes

somewhat lighter in preservatives. Both sexes of this small species were present, and the hectocotylized tip of the third right arm of the male appeared to be detached in several specimens. A closer examination revealed that where the missing tip had been, a minute growth was forming, probably a regeneration of the male portion of the arm.

#### *Octopus leioderma* (BERRY, 1911)

This is a small, smooth, "soft" octopus usually taken on a muddy sand substratum in about 50 fathoms of water. Usually the animals are considerably distorted and damaged, as they are found in the narrow crevices of the deck grates and about the scuppers. There is a definite constriction between the body and the head, the head and the arms, and another, less pronounced ridge or rim on the horizontal plane of the body, which resembles a mold-mark on a plastic toy. In coloration the animal is a pinkish-tan, livid, and when placed in preservatives it darkens to a brownish-red, lighter on the ventral surface. Both males and females were obtained from the "Winga" and the "Anna W".

#### *Opisthoteuthis californicus* BERRY, 1949

The type locality for this interesting and non-octopod appearing species is off Humboldt Bay and the majority of the known specimens has been obtained from off this portion of the California coast. The species may attain over 2 feet in diameter, and in life looks like a translucent jelly-fish veined with rust on the dorsal surface; ventrally the animal is entirely rust color. The minute fins on the dorsal surface are puzzling structures. The body is extremely soft and the name the fishermen use, "jelly-fish-octopus," seems to me to be more appropriate than the official name "flapjack devilfish." Most of the specimens were taken in excess of 300 fathoms, but it is known to occur at times in depths of only about 100 fathoms. All material in my collection came from a very soft mud substratum and was obtained for me by the "Ina," "Flicker" and "Anna W".

#### *Loligo opalescens* BERRY, 1911

A few specimens taken off Redding Rock, north of Eureka, have reached me through the "Anna W," fishing in about 100 fathoms. None of the specimens exceeded 200 mm in length; they were taken singly, not in a school of squid. In life the animal is truly opalescent, a pinkish-tan, translucent, with the chromatophores standing out in stark contrast. In death the body is opaque and when placed in preservatives, the body turns white with the red chromatophores turning dull brown.

*Meleagroteuthis hoylei* <sup>Fe</sup> PUFFER, 1900

A single, slightly mangled specimen (a female), 118 mm in length, including the arms but not the tentacles, was caught in the net of the "Flicker" in a depth of over 300 fathoms. This species is well figured by BERRY, 1912, who records it from Monterey, California. There are 2 very small specimens, bleached white, in the collection of the California Academy of Sciences; they were taken on the Cordell Bank, Marin County, California. The recent specimen was a dark purple in life with small tan, grain-like nodules on the dorsal surface, especially on the body, and until the specimen was placed into preservative, these grain-like markings were actually extruded and could be felt with the fingers of one's hand. In preservative, the color has changed to a rich purple with tiny tan grain-like markings on the body, but the small nodes now no longer may be noted.

*Galiteuthis pyllura* BERRY, 1911

The dragboat "Ina" obtained the rather diagnostic "leaf" tail of a specimen of this species amid the debris left on deck after a drag. The captain and crew noting that this was animal tissue new to them, saved the bit of flesh by freezing it in their refrigerator. In life or when found, the tissue was nearly translucent with dark reddish maculations, which in freezing turned an opaque dead white with dark red markings. Based upon BERRY's measurements of the type specimen, the Humboldt specimen must have been 350 mm long, much larger than BERRY (1912) recorded. There are some specimens, again bleached, from the Cordell Bank, in the collection of the California Academy of Sciences.

*Meroteuthis robusta* (VERRILL, 1876)

The giant squid, which is reputed to attain a length of 50 feet, has been taken by dragboats off Eureka, California. For obvious reasons, only a major research center has the necessary facilities to store preserved specimens. I have seen no fresh or living examples, but have examined some on docks at various times; I also have examined the preserved specimens in the California Academy of Sciences.

The dragboat fishermen have no love for these creatures as their size makes them difficult to handle and they often damage the nets. In coloration the preserved specimens remind me of a dark *Loligo opalescens*.

*Rossia pacifica* BERRY, 1911

"Short-bodied squid" is the vernacular name for this small, ultra-soft-bodied cuttlefish. It is usually taken in about 100 fathoms, on a sandy mud to mud bottom; it is translucent grey on the dorsal surface and greyish white on the ventral surface. It is badly mangled when mixed in with fish. It is perhaps more common than noted as the small size and very soft body allow this animal to wash between the deck grates and out the scuppers without being seen.

*Gonatopsis* sp.

There are 2 specimens of this eight armed squid in the collection of the California Academy of Sciences, taken by the "City of Eureka" in 200 fathoms of water off Eureka. To some extent these preserved animals resemble the giant squid, but they are much smaller; the 2 body fins are quite strong and the coloration is the same brownish with dark brown maculations.

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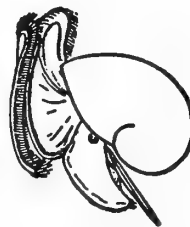
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## NOTES &amp; NEWS

# Note on the Northward Spreading of *Mya arenaria* LINNAEUS in Alaska

BY

JAMES B. GROSS<sup>1</sup>

Douglas Marine Station  
P. O. Box 185, Douglas, Alaska 99824

*Mya arenaria* (LINNAEUS, 1758) is apparently spreading northward along the Pacific shores of North America in a dispersal similar to that which occurred in northern Europe in the 17<sup>th</sup> Century.

In recent field trips to determine its distribution in nearby waters, the author found it living in sparse to dense concentrations in favorable mud and sand flats along Stephens Passage, the northern reaches of Chatham Strait and the Lynn Canal, all in southeast Alaska. It is expected that further distribution and population studies will reveal that Alaska has acquired a sizeable and heretofore unknown harvestable asset.

At present the earliest evidence of its arrival in these waters comes from a single pair of valves in the collections of the Bureau of Commercial Fisheries Biological Laboratory at Auke Bay, Alaska. This specimen was collected by J. J. Gonor in Oliver Inlet, Stephens Passage, on April 22, 1963. The specimen was in its 7<sup>th</sup> year of growth, placing the earliest known date of arrival here as 1956.

The Earthquake Study Team, under the direction of Dr. G Dallas Hanna in 1965 collected *Mya arenaria* shells in Prince William Sound. Specimens of this collection were loaned to the author by the California Academy of Sciences. The oldest of these valves, one collected at Orca Bay, was in its 6<sup>th</sup> year. Presuming that it was cast on the beach during the convulsions of the earthquake of March 27, 1964, an arrival date of 1958 can be estimated for that area.

It should be noted that the California Academy of Sciences specimens are labelled *Mya japonica* (JAY). Collections of shells of the representative subgenus from widespread areas and now in the author's possession, show ranges of variability tending to invalidate any division into separate species in spite of attempts by others to do so. However, since so much more oyster spat was brought to our West Coast from Japan than from our own eastern shores, it is quite possible that Alaska populations are descendants of either Japanese or American stock, or an admixture of both.

The author hopes to continue investigations into the origin, distribution, and population dynamics of *Mya arenaria* in Alaska and make further taxonomic studies. Valid evidence that it is a relict of past times is also being sought but to date no such evidence has been encountered.

{EDITOR'S Note: A very short time before going to press with the current issue we learned of the sudden death of Mr. Gross. We extend our sincere condolences to his relatives and many friends.}

A. M. U.

## Pacific Division

THE TWENTIETH ANNUAL MEETING of the American Malacological Union - Pacific Division was held from June 28 to July 1, 1967, at Asilomar Conference Grounds, Pacific Grove, California. The Conchological Club of Southern California acted as host for the meeting.

The Pacific Division Award of Honor was presented to Mr. ALLYN G. SMITH, California Academy of Sciences, San Francisco. The presentation was made by Dr. S. S. Berry. There was also a Chairman's Award to ROSE and JOHN Q. BURCH. Dr. Anne Hurst from the University of Reading, England, was the principal speaker at the banquet, which was held this year at the Outrigger on Monterey's well-known Cannery Row.

Officers for the coming year were elected. They are:

*Chairman:* Mrs. Fay Wolfson (San Diego)

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*Secretary:* Mrs. Barbara Good, (San Diego)

*Treasurer:* Mrs. Helen DuShane (Whittier)

*Mentor-Parliamentarian:* Dr. Rudolf Stohler (Berkeley)

<sup>1</sup> Contribution No. 34 from the Institute of Marine Science, University of Alaska.

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At a Regular Membership Meeting of the CALIFORNIA MALACOOLOGICAL SOCIETY, Inc. the following policies were adopted by unanimous vote:

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## BOOKS, PERIODICALS, PAMPHLETS

**Late Pleistocene Marine Paleoecology and Zoogeography in Central California**

by WARREN O. ADDICOTT. Geological Survey Professional Paper 523-C, 21 pp.; 4 pls.; 6 figs. in text. U. S. Government Printing Office, Washington, D. C., 1966, price 35cts.

In this excellent paper which contains a wealth of detailed data, a comparison is made of Pleistocene faunae with those of Recent time in an area extending roughly from Canada to Lower California. Conclusions are drawn as to depth of water and other ecological factors obtaining during the Late Pleistocene.

RS

**Mollusca [from below 4000 meters in the Atlantic]**

by N. H. ODHNER. Reports of the Swedish Deep-Sea Expedition 1947 - 1948. Edited by Hans Pettersson, Vol. 2, Zoology, Fascic. 4, Zoology No. 22, pp. 367 - 400, pls. 1 and 2, figs. 1 - 12 in text, November, 1960. (Göteborgs Kungl. Vetenskaps- och Vitterhets-Samhälle).

This report contains a discussion of 11 species, 8 pelecypods and 3 gastropods; 7 species are described as new. These mollusks were dredged in the Atlantic Ocean at depths varying from 4430 to 5987 m from 4 areas: the

Romanche Deep; off the coast of Venezuela; north of the West Indies; and between the Azores and Ireland. The known species, fossil and Recent, of *Vesicomya*, *Poromya*, and *Pleurotomella*, are listed.

Species described as new are: *Portlandia* (*Yoldiella*) *subcircularis*, *Poromya romanchensis*, *Cuspidaria nybelini*, *Kellyella goesi*, *Scissurella josephinae*, *Benthonella?* *kullenbergi*, and *Pleurotomella heterogramma*.

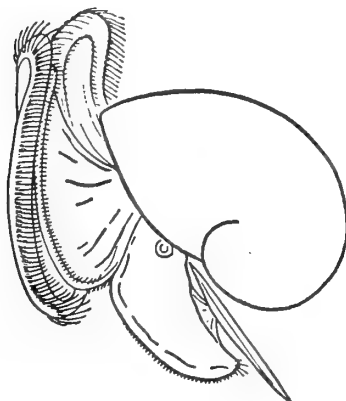
LGH

**Brachiopoda and Mollusca**

by J. HOPE MACPHERSON. Memoirs of the National Museum No. 27. pp. 199 - 384; 2 charts; 5 plates; 3 figures in text; 3 tables. 2 November 1966.

This is, in essence, a report on the Port Phillip Survey of 1957 - 1963. Although the Brachiopods are mentioned in the title of the paper, only one species is mentioned and a general remark is made to the effect that brachiopods were conspicuously absent from Port Phillip. The Amphineura are represented with about 20 species, the gastropods with about 120 species, the Bivalvia with over 40 species, the cephalopods with 12 species. However, this is not a simple enumeration of species found; Miss Macpherson has provided amplifications of the original descriptions where this seemed to be desirable. Moreover, a list of species reported from Port Phillip but not obtained during the survey of 1957-1963 is also given.

RS



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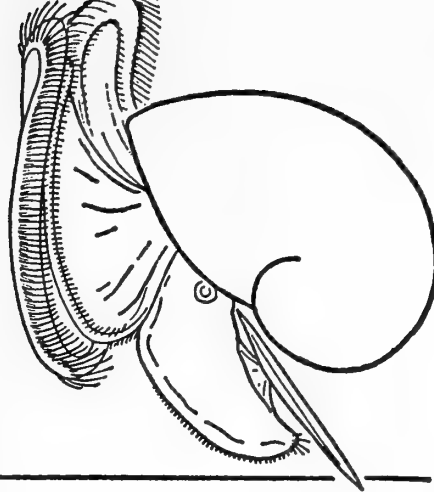
of "The Veliger," published quarterly, on the first day of July, October, January, and April, at Berkeley, California, as required by the Act of August 24, 1912.

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(signed)

R. STOHLER, *Editor*.

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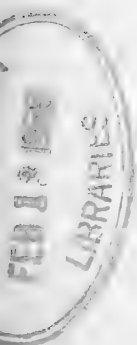
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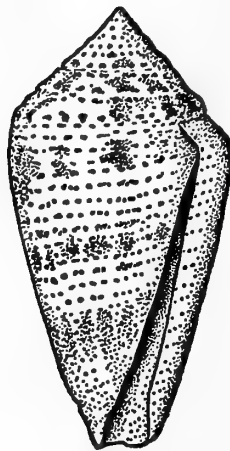
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**Note:** The various taxa above species are indicated by the use of different type styles as shown by the following examples:

**ORDER**, Suborder, **DIVISION**, Subdivision, **SECTION**,  
 SUPERFAMILY, FAMILY, Subfamily, *Genus*, (*Subgenus*).  
*New Taxa*

## Zonation in Marine Gastropods of Costa Rica and Species Diversity

BY

GERALD J. BAKUS

Allan Hancock Foundation, University of Southern California, Los Angeles, California 90007

DURING JULY AND AUGUST of 1962 I participated in the second Advanced Science Seminar in Tropical Ecology offered at the University of Costa Rica, San Jose, Costa Rica by the University of Southern California through a grant (G-21935) from the United States National Science Foundation. One of the requirements of the program was to initiate a limited research project. A comparative study was made of littoral (intertidal) zonation of gastropod mollusks on the Pacific and Atlantic coasts of Costa Rica. The littoral zone was divided into thirds for convenience, representing high, middle and low portions.

Pacific coast zonation on rocky shores was studied at three localities: Punta Caldera near Mata de Limón, Puerto Quepos and Punta Catedral, abbreviated below as ML, PQ and PC, respectively. These regions are characterized by having a mixed tide with a daily flux of 2.6 m to 3.3 m (8 to 10 feet). Mata de Limón (within the Golfo de Nicoya) has a coastline with mangroves, considerable mud by runoff from a local river and turbid water. The site of collection and observation (Punta Caldera) was reached by boat and located about 1.5 km southwest of Caldera. The shoreline is rocky and relatively barren. Brachyuran and anomuran crabs are abundant as is one of three species of barnacles living there. The bivalve mollusk *Brachidontes punctarenensis* is especially numerous. Benthic algae are low in diversity and standing crop. Puerto Quepos and especially Punta Catedral have exposed rocky shorelines. The latter region is reminiscent of rugged portions of the coast of central and northern California but the epibiota is sparse excepting brachyuran and anomuran crabs and gastropod mollusks. Long stretches of sandy beaches are found nearby and olives (*Olivella*) are abundant there. A composite portrayal of zonation among the more conspicuous gastropods is presented as follows: The supralittoral zone is occupied by *Littorina conspersa* at Mata de Limón, found as high as 10 m above the 0-tide level. No supralittoral littorines were observed at Puerto Quepos or Punta Catedral. The high littoral zone contains *L. conspersa* (ML, PQ, PC), *L. aspera* (PQ, PC), *Nerita*

*scabricosta ornata* (ML, PQ, PC), *Purpura patula pansa* (PQ, PC), *P. columellaris* (PQ, PC), and *Siphonaria gigas* (PQ, PC). The mid-littoral zone is characterized by *L. conspersa* (ML, PQ, PC), *L. aspera* (PQ, PC), *N. s. ornata* (ML, PQ, PC), *S. gigas* (PQ, PC), and *Fissurella virescens* (PQ, PC) with *Opeatostoma pseudodon* (PQ, PC), *Tegula pellisserpentis* (PQ, PC), *Thais melones* (PQ, PC) and *Acanthina brevidentata* (ML, PQ, PC) in the lowermost levels. The low littoral contains *O. pseudodon* (PQ, PC), *Tegula pellisserpentis* (PQ, PC), *Thais melones* (PQ, PC), *A. brevidentata* (ML, PQ, PC), *F. virescens* (PQ, PC), *Neosimnia* sp. (on a pink gorgonian near PC), *Conus nux* (PC), *Natica chemnitzii* (ML), *Polinices otis* (ML) and with *Thais biserialis* (ML) in the lowermost levels. Atlantic coast zonation on old uplifted limestone was studied at three localities: Portete, Puerto Limón, and Isla Uvita, abbreviated below as P, L, and U, respectively. These coastal areas are characterized by having a diurnal tide with a daily flux of about 1 m (3 feet). Portete, located about 5 km north of Puerto Limón, has a small bay which is rather rich in benthic algae and flowering plants. *Caulerpa*, *Thalassia* and the sea urchin *Diadema* are common in shallow waters. Live corals grow in pockets near the mouth of the bay. Puerto Limón has an uplifted shelf of old exposed limestone pavement pocked by numerous shallow depressions containing abundant bivalved mollusks (*Isognomon radiatus* and *Isognomon* cf. *I. bicolor*). This is especially characteristic of the shoreline north of the town. Benthic algae are diverse and relatively abundant. Numerous echinoids, ophiuroids, sea anemones, brachyuran and anomuran crabs, gastropod mollusks and several species of live corals occur in this region. Isla Uvita is located about 1 km offshore from the town of Puerto Limón. The windward side is rocky and precipitous; the crab *Grapsus grapsus* is a rapid moving and common representative there. The leeward side contains a fringing reef with a sandy lagoon between the island and the reef. Gastropod zonation, discussed below, was studied on the leeward side.

Thousands of small black snails (*Cerithium variable*) are found on the sand in the *Thalassia* beds within the lagoon. A composite portrayal of zonation among the more conspicuous gastropods is presented as follows: The supralittoral zone contains *Tectarius muricatus* (P, L) which is found as high as 2 m above the 0-tide level. *Littorina ziczac* (P, L) occurs in the lowermost levels of this zone. The high littoral zone contains *L. ziczac* (P, L) and *L. nebulosa* (U). The mid-littoral zone is characterized by *Purpura patula* (U), *Thais haemastoma floridana* (P), *Littorina meleagris* (L), *Conus mus* (L, U), *Nerita fulgurans* (P), *N. tessellata* (P), and with *Cittarium pica* (L, U) in the lower levels. The low littoral zone contains *Cittarium pica* (L, U), *N. fulgurans* (P), *Neritina virginea* (P) and *Leucozonia nassa* (L). A list of all mollusks collected alive as well as shells is presented below in the appendix. Specimens taken are now located in the Los Angeles County Museum of Natural History under the care of Dr. James H. McLean, Curator of Invertebrate Zoology.

## DISCUSSION

The supralittoral and high littoral zones on both Pacific and Atlantic coasts are dominated by Littorinidae. *Purpura*, *Nerita* and *Siphonaria* seemed to be missing from these zones on the Atlantic coast. It is common to find littorines predominating in the high littoral and supralittoral zones in part because of their resistance to desiccation. ROSEWATER (1963) reviewed the literature on desiccation in littorines. *Tectarius muricatus* lived for 18 months in a box. *Littorina ziczac* lived for 7 months with only infrequent wetting. Both Pacific and Atlantic coasts of Costa Rica samples contain supralittoral and littoral gastropods in which roughly half are carnivores and half herbivores. Visual observations indicated that Pacific coast stations supported about twice the standing crop of gastropods as that of the Atlantic coast but quantitative information is needed for verification. If this is a true measure of standing crop a paradox is encountered because the diversity and standing crop of benthic algae are very low along the Pacific coast; it is one of the poorest regions for benthic algae in the world (Dr. E. Yale Dawson, personal communication). Some of the reasons for differences in benthic algae along the two coasts are discussed by DAWSON (1962). However, primary production by benthic algae must be reasonably high on the Pacific coast, despite high turbidity in many areas, in order to account for the apparently greater standing crop of gastropods. It may be that benthic algae seem to be depauperate on the Pacific Coast because of high intensity grazing by invertebrates

and perhaps fishes. This same phenomenon is characteristic of many other tropical regions (BAKUS, 1966a and in press).

The pioneer taxonomic work on the mollusks of Pacific Central America is that of PILSBRY & LOWE (1932). Comprehensive information on Pacific Coast mollusks is found in KEEN (1958) and on Caribbean mollusks in WARMKE & ABBOTT (1961). Recently, PAINE (1966) studied briefly the feeding relationships between two small carnivorous gastropods, a mytilid (probably *Brachidontes*) and barnacles near Mata di Limón, Costa Rica, and compared them with similar observations in the northern Gulf of California and at Mukkaw Bay, Washington. The work of PAINE (1966) and observations by the present author agree in that the local species diversity of rocky littoral and supralittoral mollusks of the Pacific Coast of Costa Rica is low. This leads to the interesting question of why does local species diversity appear to be low in Costa Rica, slightly greater in Washington and high in the northern Gulf of California. PAINE (1966) presented a logical hypothesis supported in part by field data. He stated (*op. cit.*, p. 65): "Local species diversity is directly related to the efficiency with which predators prevent the monopolization of the major environmental requisites of one species." PAINE did not consider the importance of the local substratum on the settling of larvae and spores, in order that predators have something with which to "prevent" monopolization. GIBSON (1966), from studies on foraminiferal diversity in Mississippi Sound, Gulf of Mexico, concluded that regions of high diversity are associated with stable physico-chemical environments. Both PAINE and GIBSON have contributed to ecological theory but their viewpoints are restrictive. For example, if GIBSON's hypothesis were generally true, then the rocky and sandstone intertidal region of the northern Gulf of California (where water temperatures vary between 15°C and 31°C during the year, where there is a relatively long history of runoff from the Colorado River, where a tidal flux of up to about 7 m (22 feet) occurs daily, and where the ambient air temperature may reach well over 38°C (100°F) in July-August and approach freezing (0°C) in December-January) should have a relatively low species diversity. Contrarily, the northern half of the Gulf of California contains a high diversity of littoral animals (GARTH, BELTRAN, & SAVAGE, 1960; McLEAN, 1961; PAINE, 1966), and the Gulf of California may support the greatest diversity of shallow water invertebrates in the world (PARKER, 1964). DUSHANE & POORMAN (1967) reported over 1000 species of mollusks from Guaymas, Sonora, Mexico. Studies conducted by students and the present author on the fauna of the region of Peñasco, Sonora, Mexico (northern Gulf of California) have indicated

that local species diversity of littoral invertebrates is often high.

GIBSON (1966) made the generalization that in the distribution of marine benthon, species variety is lowest near shore and greatest in deeper portions of the continental shelf. However, the diversity of scleractinian corals, coral reef fishes and even temperate latitude crabs (Dr. John Garth, personal communication) is usually greatest in shallow waters. This probably holds true for many other animal groups, especially those associated with scleractinian corals. More significantly, both GIBSON and PAINE overlooked the very important aspect of geological history. For example, the northern Gulf of California has a unique history. It has received organisms from the Pacific Ocean by way of openings in the present Baja Peninsula (see DURHAM & ALLISON, pp. 47-91 in GARTH, BELTRAN & SAVAGE, 1960), it has received other organisms from the Caribbean (see GARTH, BELTRAN & SAVAGE, 1960 and BAKUS, 1966b: 423), and several migrations of surface water isotherms have occurred along the coast of southern California and Baja California (HUBBS, 1960, 1961; BANDY, 1967). The northern Gulf of California has a complex biota consisting of elements from the cold temperate, warm temperate, subtropical and tropical regions. Moreover, it has a moderately high degree of endemism (GARTH, BELTRAN & SAVAGE, 1960) and curious summer and winter algal communities (DAWSON, 1944: 200). Much of the Pacific coast of Costa Rica has considerably less diversity. The rocky littoral zone contains tropical forms that must resist high air temperatures and desiccation, excessive turbidity and frequent exposure to fresh-water during part of the year, and probably periodic effects of upwelling. On the other hand, it is likely that the effects of predaceous, grazing and browsing fishes on the littoral biota are more pronounced in Costa Rica than in the northern Gulf of California (BAKUS, 1966a).

In conclusion, more information, particularly of a quantitative nature, is needed to better understand intertidal zonation in Central America. Hypotheses that deal with species diversity in the marine environment, should be considered only as parts of an enormously complex group of variables that change with time.

### ACKNOWLEDGMENT

I would like to thank the following persons: Jay M. Savage for introducing me to tropical biology; the late E. Yale Dawson for introducing me to benthic marine algae and for his companionship on field trips throughout Costa Rica; W. Jake Houk for a collection of shells from Mata de Limón, Costa Rica; James H. McLean for verifications, corrections and additions on my identifications

of marine mollusks taken in Costa Rica; Manuel M. Murillo for a translation of a summary into Spanish; and James H. McLean, Los Angeles County Museum of Natural History, Jay M. Savage, Kristian Fauchald, Manuel M. Murillo, Amada Reimer, Department of Biological Sciences, University of Southern California, and Orville L. Bandy, Department of Geology, University of Southern California, for suggestions and criticisms.

### APPENDIX

List of mollusks collected in Costa Rica, all of which are on deposit in the Los Angeles County Museum of Natural History

#### A. Pacific Coast:

1. Punta Caldera, near Caldera, Costa Rica: live mollusks, littoral and supralittoral, collected by G. Bakus, 20 July 1962.

<i>Acanthina brevidentata</i> (WOOD, 1828)	1
<i>Anachis</i> sp.	7
<i>Anachis</i> sp.	2
<i>Brachidontes puntarenensis</i> (PILSBRY & LOWE, 1932)	6
<i>Littorina conspersa</i> PHILIPPI, 1847	24
<i>Natica chemnitzii</i> PFEIFFER, 1840	2
<i>Nerita scabricosta ornata</i> SOWERBY, 1823	1
<i>Olivella zanoeta</i> (DUCLOS, 1835)	7
<i>Polinices otis</i> (BRODERIP & SOWERBY, 1829)	1
<i>Thais biserialis</i> (BLAINVILLE, 1832)	7
<i>Thais triangularis</i> (BLAINVILLE, 1832)	1
<i>Tricolia mazatlanica</i> (STRONG, 1928)	1

2. Mata de Limón, Costa Rica: shells cast up on beach, all but one inhabited by hermit crabs, all but one collected by Jake Houk, 21 July 1962.

<i>Acanthina brevidentata</i> (WOOD, 1828)	5
<i>Anachis fluctuata</i> (SOWERBY, 1832)	1
<i>Cantharus ringens</i> (REEVE, 1846)	2
<i>Cantharus vibex</i> (BRODERIP, 1833)	1
<i>Cassis centiquadrata</i> (VALENCIENNES, 1832)	3
<i>Cerithidea pulchra</i> (C. B. ADAMS, 1852)	2
<i>Cerithidea valida</i> (C. B. ADAMS, 1852)	1
<i>Cymatium gibbosum</i> (BRODERIP, 1833)	1
<i>Cymatium vestitum</i> (HINDS, 1844)	1
<i>Pitar lupanaria</i> (LESSON, 1830), collected by G. Bakus, 20 July 1962	1
<i>Rhinocoryne humboldti</i> (VALENCIENNES, 1832)	2
<i>Tegula byroniana</i> (WOOD, 1828)	1
<i>Thais triangularis</i> (BLAINVILLE, 1832)	1
<i>Turritella</i> sp. (juvenile)	2

3. Puerto Quepos, Costa Rica: live mollusks, littoral and supralittoral, collected by G. Bakus, 20 July 1962.

<i>Acanthina brevidentata</i> (WOOD, 1828)	2
<i>Littorina aspera</i> PHILIPPI, 1846	10
<i>Littorina conspersa</i> PHILIPPI, 1847	12
<i>Nerita scabricosta ornata</i> SOWERBY, 1823	4
<i>Opeatostoma pseudodon</i> (BURROW, 1815)	2
<i>Planaxis planicostatus</i> SOWERBY, 1825	1
<i>Purpura columellaris</i> (LAMARCK, 1822)	2
<i>Purpura patula pansa</i> GOULD, 1853 (?1852)	2
<i>Siphonaria gigas</i> SOWERBY, 1825	1
<i>Tegula pellisserpentis</i> (WOOD, 1828)	3
<i>Thais melones</i> (DUCLOS, 1832)	5

4. Puerto Quepos, Costa Rica: shells cast up on beach, collected by G. Bakus, 20 July 1962.

<i>Opeatostoma pseudodon</i> (BURROW, 1815)	1
<i>Purpura patula pansa</i> GOULD, 1853 (?1852)	1
<i>Pyrene labiosa</i> (SOWERBY, 1822)	2
<i>Siphonaria gigas</i> SOWERBY, 1825	3
<i>Tegula panamensis</i> (PHILIPPI, 1849)	1
<i>Tegula pellisserpentis</i> (WOOD, 1828)	1

5. Near Punta Catedral (1½ km south), Costa Rica, live mollusks, littoral and shallow sublittoral, collected by G. Bakus, 21 July 1962.

<i>Conus nux</i> BRODERIP, 1833	1
<i>Fissurella virescens</i> SOWERBY, 1835	1
<i>Neosimnia</i> sp. (on pink gorgonian)	1

6. Near Punta Catedral (1½ km south), Costa Rica: shells cast up on beach, collected by G. Bakus, 21 July 1962.

<i>Conus purpurascens</i> SOWERBY, 1833	4
<i>Cypraea arabicula</i> LAMARCK, 1811	2
<i>Cypraea cervinetta</i> KIENER, 1843	3
<i>Cypraea robertsi</i> HIDALGO, 1906	1
<i>Fissurella virescens</i> SOWERBY, 1835	2
<i>Oliva spicata</i> (RÖDING, 1798)	5
<i>Strombus peruvianus</i> SWAINSON, 1823	1
<i>Trigoniocardia guanacastensis</i> (HERTLEIN & STRONG, 1947)	3
valves only	3

B. Atlantic Coast:

7. Portete, Costa Rica: live mollusks, littoral and supralittoral, collected by G. Bakus, 4 August 1962.

<i>Anadara ovalis</i> (BRUGUIÈRE, 1789)	1
<i>Isognomon radiatus</i> (ANTON, 1839)	1
<i>Leucozonia nassa</i> (GMELIN, 1791)	3

<i>Littorina nebulosa</i> (LAMARCK, 1822)	11
<i>Littorina ziczac</i> (GMELIN, 1791)	1
<i>Nerita fulgurans</i> GMELIN, 1791	3
<i>Nerita tessellata</i> GMELIN, 1791	1
<i>Neritina virginea</i> (LINNAEUS, 1758)	15
<i>Tectarius muricatus</i> (LINNAEUS, 1758)	3
<i>Thais haemastoma floridana</i> (CONRAD, 1837)	4

8. Portete, Costa Rica: shells cast up on beach, collected by G. Bakus, 4 August 1962.

<i>Charonia variegata</i> (LAMARCK, 1816)	1
<i>Cittarium pica</i> (LINNAEUS, 1758)	1
<i>Columbella mercatoria</i> (LINNAEUS, 1758)	1
<i>Cypraea spurca acicularis</i> GMELIN, 1791	1
<i>Strombus raninus</i> GMELIN, 1791	1

9. Puerto Limón, Costa Rica: live mollusks, littoral and supralittoral, collected by G. Bakus, 7 July 1962.

<i>Cittarium pica</i> (LINNAEUS, 1758)	1
<i>Conus mus</i> HWASS, 1792	1
<i>Isognomon</i> cf. <i>I. bicolor</i> (C. B. ADAMS, 1845)	3
<i>Isognomon radiatus</i> (ANTON, 1839)	1
<i>Leucozonia nassa</i> (GMELIN, 1791)	1
<i>Littorina meleagris</i> (POTIEZ & MICHAUD, 1838)	2
<i>Littorina ziczac</i> (GMELIN, 1791)	1
<i>Modulus modiolus</i> (LINNAEUS, 1758)	1
<i>Tectarius muricatus</i> (LINNAEUS, 1758)	1
<i>Vasum muricatum</i> (BORN, 1778)	1

10. Puerto Limón, Costa Rica: shells cast up on beach, collected by G. Bakus, 7 July 1962.

<i>Arcopagia fausta</i> (PULTENEY, 1799)	1
<i>Cerithium eburneum</i> BRUGUIÈRE, 1792	1
<i>Columbella mercatoria</i> (LINNAEUS, 1758)	1
<i>Conus mus</i> HWASS, 1792	1
<i>Crassispira</i> sp.	1
<i>Isognomon</i> sp.	1
<i>Littorina ziczac</i> (GMELIN, 1791)	1
<i>Nerita fulgurans</i> GMELIN, 1791	4
<i>Nerita tessellata</i> GMELIN, 1791	2
<i>Tectarius muricatus</i> (LINNAEUS, 1758)	1

11. Puerto Limón, Costa Rica: mollusks in shallow sublittoral, collected by G. Bakus, 8 July 1962.

<i>Vasum muricatum</i> (BORN, 1778)	2
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12. Isla Uvita, Costa Rica: live mollusks, littoral and supralittoral, collected by G. Bakus, 8 July 1962.

<i>Cerithium litteratum</i> (BORN, 1778)	2
<i>Cerithium variabile</i> C. B. ADAMS, 1852	2

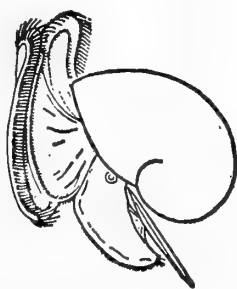
- Cittarium pica* (LINNAEUS, 1758) 1  
*Codakia orbicularis* (LINNAEUS, 1758) 1  
*Conus mus* HWASS, 1792 1  
*Leucozonia nassa* (GMELIN, 1791) 1  
*Littorina nebulosa* (LAMARCK, 1822) 4  
*Purpura patula* (LINNAEUS, 1758) 1

13. Isla Uvita, Costa Rica: shells cast up on beach, collected by G. Bakus, 8 July 1962.

- Cittarium pica* (LINNAEUS, 1758) 2  
*Conus mus* HWASS, 1792 2  
*Cymatium pileare* (LINNAEUS, 1758) 1  
*Littorina nebulosa* (LAMARCK, 1822) 2

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## Western Australian Cowries

### A Second, Revised, and Expanded Report

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(Plates 21 to 34; 5 Maps)

#### INTRODUCTION

SEVERAL IMPORTANT FACTORS have made this sequel to my 1964 report advisable. First is the need to record subsequent information gathered in the area; new range extensions are given, with special reference to the area including Port Hedland, Onslow, the outer shore of North West Cape from Yardie Creek south to Dongara; moreover, this report includes information gathered on a recent collecting expedition to the Abrolhos Islands for the express purpose of learning the extent of cypraeid populations there and the relationships of the island fauna to that of the mainland.

Secondly, the new generic arrangement of SCHILDER (1965, 1966), in which the species are listed in order from the most primitive to the most specialized forms, has been adopted; note should be taken, therefore, that the taxonomic arrangement used here will supersede that of CATE, 1964. A limited number of species has been shifted into different genera, and subspecific recognition has been accorded a West Australian form of *Cypraea leviathan* SCHILDER & SCHILDER, 1937, *Zoila friendii* (GRAY, 1831), and *Palmadusta saulae* (GASKOIN, 1843).

Thirdly, photographs have been added to illustrate all the species of cowries presently known to inhabit West Australian waters, from Cape Leeuwin in the south to Port Darwin in the north. These illustrations will assist in identification, and the revised text will offer a uniform taxonomic approach to the species and their generic relationships.

The locality data as shown in CATE, 1964, will not be repeated in the new text, unless they are incidental to the listing of a newly recorded species in a previously reported area. It has also been necessary to omit latitude and longitude readings in most instances, since many of the remote collecting stations do not appear on maps. In these cases

appropriate bearings in miles will be given in relation to better known localities.

I was able to examine a great number of cowrie species in the South Australian Museum, Adelaide, and in the West Australian Museum, Perth, as well as in many private West Australian collections. I found that most of the shells fell within the size-range of the largest and smallest shell dimensions recorded in CATE, 1964. It therefore seemed appropriate to take an average of their sizes for use in this overall study, as a median of shell dimension. The five figures given in parentheses are, in order: length, width, and height (in millimeters), number of teeth on outer lip, and on the columellar lip. The numbers in parentheses in the text under individual species discussions indicate the locality references. The list of localities is amended to include a South Australian locality where a West Australian species has been recently discovered, or overlaps in a natural range extension.

#### THE HOUTMAN ABROLHOS ISLANDS

The Houtman Abrolhos Islands Group, often referred to as the "Houtman Rocks," is an archipelago lying approximately 49 miles off the west coast of Australia in the Indian Ocean, almost due west of Geraldton. Named for its discoverer, Cornelis de Houtman, it consists of three separate groups of islands lying approximately parallel to the mainland, between the latitudes 28° 15' and 29° 01' South.

Little has heretofore been known about the mollusca living in these remote island waters; our limited knowledge of the fauna is necessarily based upon the shells found in fishermen's crayfish pots, and upon visits to the islands by Archer Whitworth of Geraldton in 1964 and a recent trip of my own.

During October, 1966 (it was Spring in Australia) I visited the Houtman Abrolhos Islands, personally collecting at nearly every island of the southern Pelsart group and of the middle Easter group. The cowrie populations living in the intertidal zones were sampled and representative lots of each available species were sent home for study. In earlier years, Archer Whitworth, Geraldton, and James "Jimmy" Seabrook of Perth have made repeated trips to the islands, the former working the littoral and adjacent shallow water, the latter, in the motor vessel "*Lancelin*" of the Fisheries Department, Perth, using baited crayfish pots and limited dredging in the islands and other mainland offshore reef areas. It is interesting to note that many of the common mainland shore cowries are absent, as far as we have been able to determine from the Abrolhos fauna. The ecological conditions seem much the same in many instances, although the islands have, generally speaking, much rougher water and are more exposed to the storm force of the normal southerly winds. The island waters are perhaps more varied as to depth, condition of food, food source, and substrate (there appears to be a noticeable scarcity of algae; a large portion of the coral is living, thus being devoid of marine plants) and in the distribution of sand, mud, and dead coral. Shallow water — scarcely ever more than 30 fathoms deep — and the combination of many reef patterns in and out of the water, plus the endless broad, shallow-water, spongy, white coral sand flats, and minimal coral and rock habitats, must surely affect the distribution of many of the mainland mollusks.

Aside from the collectors already mentioned, the following persons should also be listed: Alec Gilbertson, Max Cramer, George Barker, Martin van der Oord, W. Hemmley, Joseph Burton, Terry Butterworth, O. Hewitt of Geraldton; F. I. "Sonny" Healy, Dongara; and Edward Nickles of Mandurah. These and many others have contributed in one way or another with specimens and information, all of which have been used in this study. For the most part these men are cray fishermen, and are to be credited for having discovered and made available such rare deep water species as *Bernaya catei* SCHILDER, 1963, *Zoila marginata* (GASKOIN, 1849), *Z. venusta* (SOWERBY, 1846), the northern form of *Z. friendii* (GRAY, 1831), *Z. rosselli* COTTON, 1948, and the round northern form of *Cypraea reevei* SOWERBY, 1832. These rare species and others are found feeding on the bait (often fish, dried meat, but more often than not on dried split lamb's heads and other dried bone material) set in the crayfish pots.

The Wallabi Group to the north (see map) includes North Island, East and West Wallabi Islands, with North East Reef, Morning Reef, Noon Reef, and Evening Reef

providing the most important collecting areas in this section.

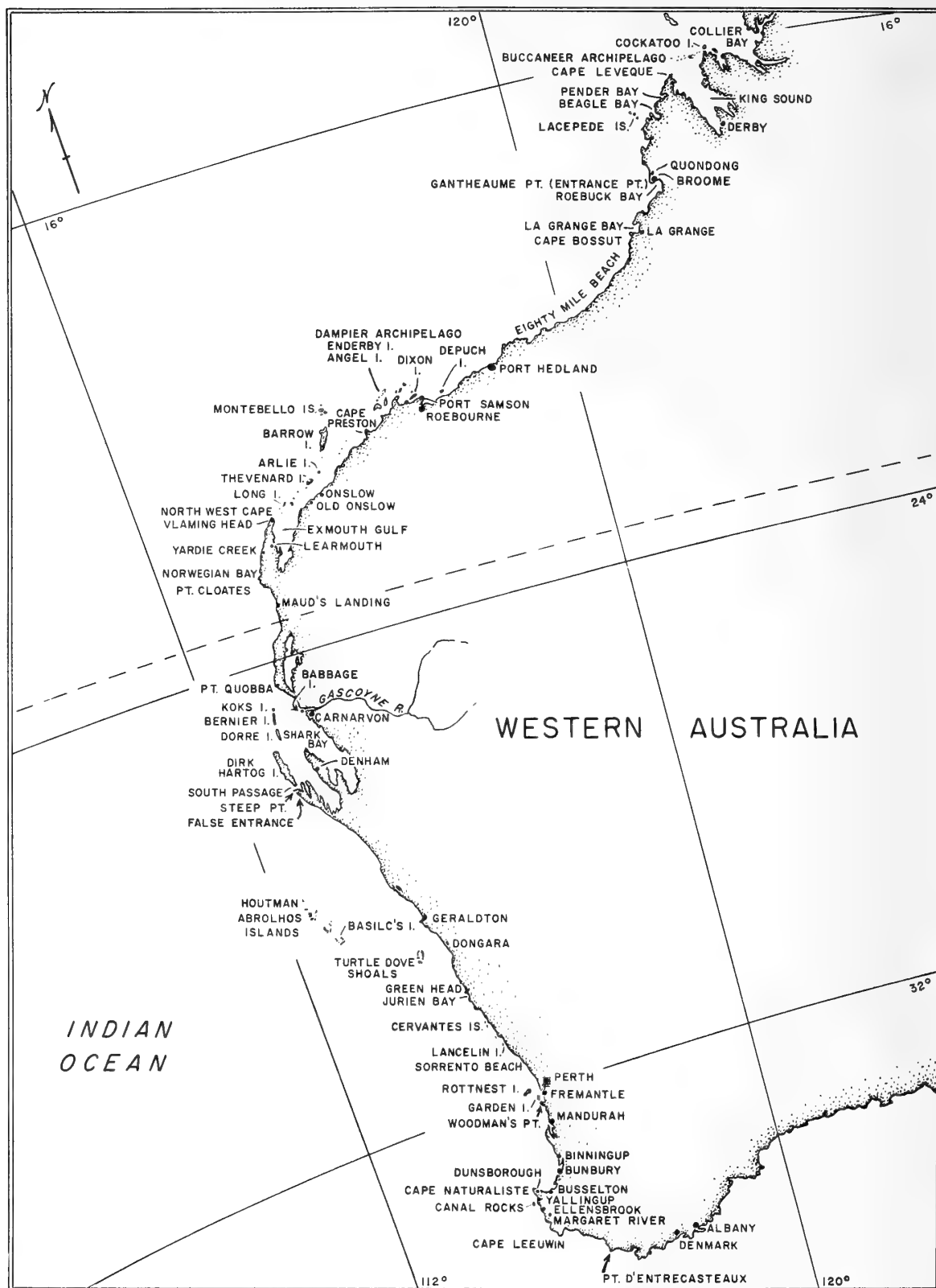
To the south of Middle Channel is the central (or middle) Easter Group, made up of numerous small islands, barely 8 to 10 feet above high water level, the largest and most important of which is Rat Island. It was at one of the fishermen's huts here that we made our headquarters during our stay at the Houtman Abrolhos Islands. Of this group Little North and Sandy Islands are the most recent of the many growing reefs to develop a permanent footing above high water mark.

The southernmost link of this coral island chain is the Pelsart Group (named after Francisco Pelsart, Captain of the Dutch trading vessel *Batavia*, wrecked in these islands on June 4, 1629), also referred to as the Southern Group, with its main island bearing the same name. The Zeewyk Channel separates this group from the Easter Group complex. Made up of a combination of reefs, partially submerged jetties, interior landlocked lagoons that rise and fall with the tide, and atoll-like sand spits, it provides excellent collecting stations, the most important of which is at Wreck Point at the west end of mile-long Pelsart Island. Otherwise, the best areas are Mangrove Island, Hummock Island, Square Island, White Banks, and King Reef, the latter becoming awash at high tide and accessible only at low tide, and then for only a short time.

While *Zoila friendii vercoi* SCHILDER, 1930 is almost surely a South Australian subspecies of *Z. friendii* (GRAY, 1831), there are labels in Museum collections and elsewhere indicating a questionable incidence for these shells in West Australian waters. I am omitting them here as not being a part of the western fauna, but it seems pertinent to remark on them briefly at this time (see Plate 23, Figure 11, which illustrates this form). Cate coll. no. C 1706 (83.3 53.1 39.0 26 10) = (2a); no. C 3500 (76.8 49.2 35.4 24 9) = (59a); no. C 3501 (73.8 44.0 34.3 22 5) = (59a) are additional specimens for comparative statistics.

Although geographically adjacent to *Zoila friendii friendii* of Western Australia, *Z. friendii vercoi* may be considered as being an intra-population variant. WILSON & SUMMERS (1966) may be correct in their appraisal of these shells. Among other proposals, they suggest placing *Z. f. vercoi* into synonymy with *Z. f. friendii* as being "either clinical or subject to non-geographical, inter-locality variation." This may possibly be true. One way or the other, the south Australian form *Z. f. vercoi* does possess apertural and teeth arrangement so characteristic of *Z. f. friendii*, linking them very closely to one another.

I have examined 11 specimens of this subspecies, in the South Australian Museum, the West Australian Museum, and in my own collection. The answer is always the

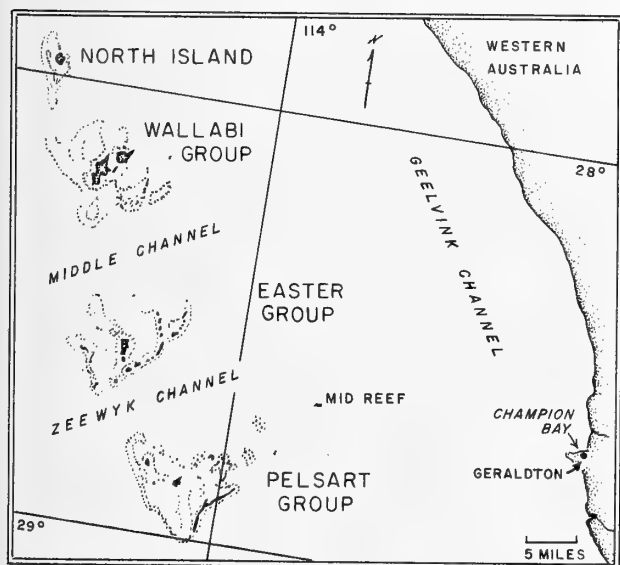


same; the mollusks from the southwest coast localities do vary remarkably in morphological development. A student could say there is a distinct difference in these shells, and could maintain there is some point of geographical separation between the southern and western populations in the area between Cape Naturaliste and Cape Leeuwin, though it is a narrow one and open to possible question. The subspecies, *Zoila friendii vercoi*, does retain many of the shell characters of the western nominate species. These would include the familiar apertural appearance, the number of teeth (almost never more than 6 to 10 on the abapical columella), and their arrangement. Particularly unifying these two variants are the limited and knobby, comparatively rudimentary teeth on the abapical quarter of the columellar lip, adjacent to the fossula; the remaining three fourths of the columella, adapically, is normally smooth and without teeth. However, these shells are distinctive enough, so that for purposes of distinguish-

their contributions of shells and information toward this work, I wish to express my gratitude to Molly and Robert Gedling, to Iris and Robert Thomas, both families (the latter in the earlier days of this study) light keepers at Vlaming Head, North West Cape. To Brian Kember, Port Hedland, to Theodore Crake, Broome, to Mrs. D. Clarke, Onslow, to Ned Harrold, Victoria Park, Perth, to Dr. Helene Laws, South Australian Museum, Adelaide, and to Dr. Barry Wilson, West Australian Museum, Perth, for permission to inspect the collections in their care; to Mrs. Emily Reid for the excellent maps; to Takeo Susuki for assistance with photography; to Archer Whitworth, a dear friend of long standing living in Geraldton; and to Jean Cate for assistance in many helpful ways.

## LOCALITY INDEX

Due to the wild, uninhabited nature of much of the present coastline of West Australia, distances given, and many of the indicated localities, are only approximate. Even so, they are reasonably correct as to landfall, and truly represent the localities and ranges of the Cypracidae as we know them today.



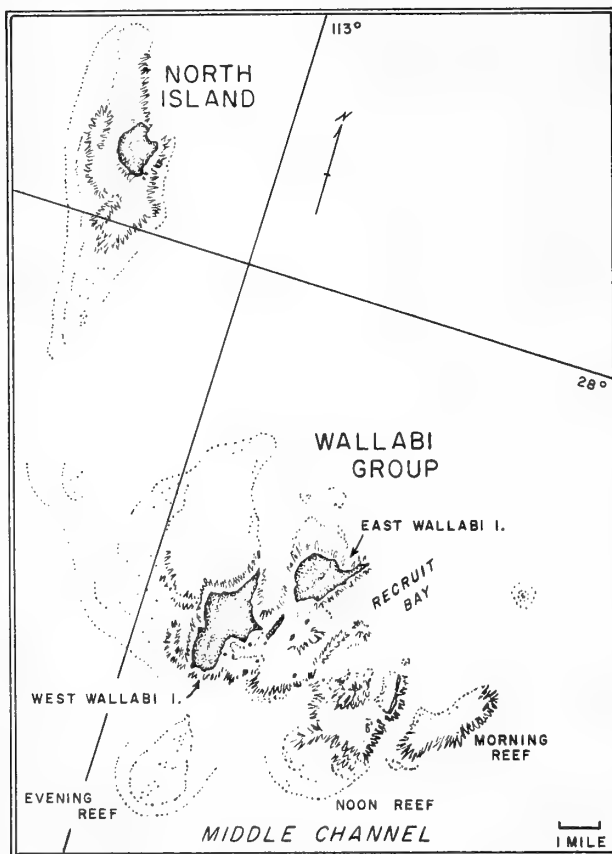
ing the south southwest Australian shells I am tentatively retaining the available name for this 'end of cline' group as a South Australian subspecies (see Table 1 for comparative statistics).

## ACKNOWLEDGMENT

As is always the case in a work like this, many persons have given generously of their help in countless tangible and intangible ways; to them all I express my thanks. In addition to those mentioned elsewhere in this paper for

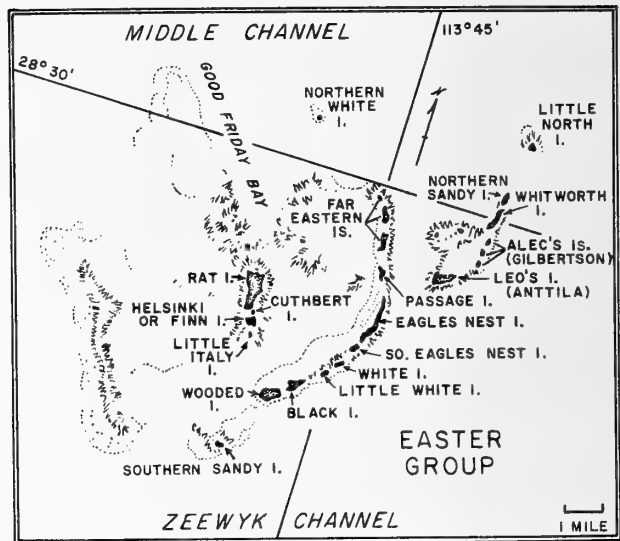
1. Abrolhos Islands
2. Airlie Island, 16 miles NNE of Onslow
- 2a. Albany, South Australia
3. Albany, Frenchman's Bay
4. Alec Gilbertson Island, Easter group, Abrolhos Islands
5. Alec Finlay Island (the nook), Abrolhos Islands
6. Anchor Island, 5 miles off-shore, 22 miles NW of Onslow
7. Angel Island, Dampier Archipelago
8. Anttila Island, Abrolhos Islands
9. Arch Whitworth Island, Abrolhos Islands
10. Ashburton Island, approximately 11 miles W of Onslow
14. Busselton, Geopraphe Bay
15. Barrow Island, 60 miles N of Onslow
16. Basil's Island, Abrolhos Islands
17. Bathurst Island, 60 miles NE of Darwin
18. Bathurst Point, Rottnest Island
19. Bernier Island, Shark Bay
20. Binningup, approximately 15 miles N of Bunbury
21. Black Island, Abrolhos Islands
22. Bossut, southern point of La Grange Bay
23. Bowes River, 28 miles N of Geraldton
24. Broome, Roebuck Bay
25. Broome, Coconut Well
- 25a. Bunbury
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28. Capel, 17 miles S of Bunbury
29. Cape Bossut
30. Calgadup Brook, near Margaret River S of Cape Naturaliste
- 30a. Cape Jervis, South Australia
31. Cape Leeuwin
32. Cape Naturaliste

33. Cape Preston, Onslow
34. Cape Villaret, 30 miles N of Broome
- 34a. Carnac Island, just N of Garden Island
35. Carnarvon
36. Cervantes Island
37. Chabjuwardoo Bay, S of Point Cloates
38. Coburn
39. Cockburn Sound, S of Fremantle
40. Cockburn Sound, Pamela Bank off Woodman's Point
41. Cockatoo Island, Buccaneer Archipelago
42. Cottesloe Beach, Perth
43. Cowrie Creek, 35 miles S of Port Hedland
44. Cambridge Gulf, Wyndham, 250 miles S of Darwin
45. Darwin
46. Delambre Island, Dampier Archipelago
47. Direction Island, 7 miles NE of Onslow
48. Dirk Hartog Island, adjacent to Shark Bay
49. Dixon Island, off Port Samson
52. Dongara



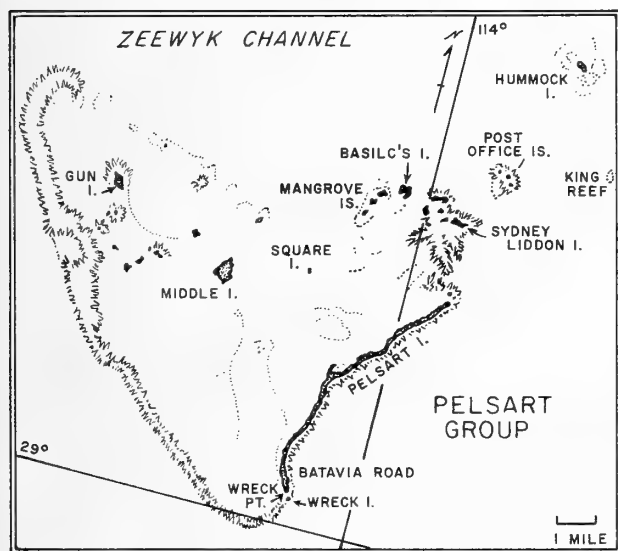
53. Dongara, Leander Reef  
Dongara, Turtle Dove Shoal -- see 156
54. Dorre Island, S of Bernier Island, Shark Bay
57. Eagle Nest Island, Abrolhos Islands
58. Eagle Nest Island (south island), Abrolhos Islands
59. Enderby Island, Dampier Archipelago

- 59a. Esperance, South Australia
60. Exmouth Gulf
61. Fremantle
- 61a. Fremantle, off entrance to Swan River in 30 feet, on sponge
62. Far Eastern Islands (3), Abrolhos Islands



- 62a. False Entrance, 12 miles SSE of Steep Point, outer Denham peninsula
63. Flat Reef, west end of West Wallabi Island, Abrolhos Islands
64. "Five Mile Beach," 5 miles S of Vlaming Head, N. W. Cape
65. Garden Island
66. Geelvink Channel, Abrolhos Islands
67. Geographe Bay
68. Geraldton
69. Glenroy Station, 10 miles S of Onslow
71. Good Friday Bay, N of Rat Island, Abrolhos Islands
- 71a. Green Head, approximately 140 miles N of Perth
- 71b. Grindal Island, near Port Lincoln, South Australia
72. Gun Island, Abrolhos Islands
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76. Hopetown Beach, south coast of West Australia
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80. King Sound
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92. Little White Island, Abrolhos Islands
93. Locker Island, 30 miles SW of Onslow
94. Long Island, 32 miles W of Onslow
95. Ludlow, 8 miles N of Busselton

97. Mandurah, approximately 35 miles S of Fremantle
98. Maud's Landing, approximately 135 miles N of Carnarvon
99. Middle Channel, Abrolhos Islands
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102. Ningaloo Woolshed, 200 miles N of Carnarvon
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105. Norwegian Bay, Whaling Station N of Point Cloates
106. North West Cape
107. Quondong, 35 miles N of Broome



108. Onslow
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110. Passage Island, Abrolhos Islands
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113. Pender Bay, Bell Point
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115. Point Murrat, Exmouth Gulf
116. Point Samson, 9 miles N of Roebourne
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- 117a. Port Darwin
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119. Port Hedland
120. Port Lincoln, South Australia
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- 121a. Quindalup, Geographe Bay
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<i>lutea</i> .....	221, 231	<i>thersites</i> .....	222, 223
<i>lynx</i> .....	218, 219, 226	<i>thielei</i> .....	221, 231
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<i>nucleus</i> .....	220, 229	<i>vitellus</i> .....	219, 226
<i>nugata</i> .....	230	<i>walkeri</i> .....	220, 229
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<i>pallidula</i> .....	221, 231	<i>ziczac</i> .....	221, 231

## SYSTEMATIC LIST

## CYPRAEIDAE FLEMING, 1828

Hist. Brit. Anim., 330 (em.) (Edinburgh)

## CYPRAEORBINAE SCHILDER, 1939

Arch. Molluskenk. 71: 165

## Bernayini SCHILDER, 1927

Arch. Naturgesch. 91/A 10: 88

*Bernaya* JOUSSEAUME, 1884

(Naturaliste 1884: 414, nom. nud.)

Bull. Soc. Zool. France 9: 88; 1884

## (Bernaya) JOUSSEAUME, 1884

> Type species: *Cypraca media* DESHAYES, 1835 <

Descr. coq. foss. env. Paris 2, 723, 95: 37 - 38

1. *Bernaya (Bernaya) catei* SCHILDER, 1963

The Veliger 5 (4): 127

*Zoila* JOUSSEAUME, 1884

(Naturaliste 1884: 414, nom. nud.)

Bull. Soc. Zool. France 9: 89; 1884

> Type species: *Cypraca friendii* GRAY, 1831 <2. *Zoila friendii friendii* (GRAY, 1831)

Zool. Misc. 1: 35

3. *Zoila friendii jeaniana* CATE, subspec. nov.4. *Zoila venusta* (SOWERBY, 1846)

Proc. Linn. Soc. London, prt. 1: 314

5. *Zoila marginata* (GASKOIN, 1849)

Proc. Zool. Soc. London for 1848: 91

6. *Zoila rosselli* COTTON, 1948

Trans. Roy. Soc. So. Austral. 72 (1): 30; plt. 1

7. *Zoila decipiens* (E. A. SMITH, 1880)

Proc. Zool. Soc. London for 1880: 482; plt. 48, fig. 8

*Mauritia* TROSCHER, 1863

Das Gebiß der Schnecken 1: 205

> Type Species: *Cypraca mauritiana* LINNAEUS, 1758 <

Systema Naturae, ed. 10: 721

## (Arabica) JOUSSEAUME, 1884

Naturaliste 1884: 414

> Type species: *Cypraca arabica* LINNAEUS, 1758 <

Systema Naturae, ed. 10: 718

8. *Mauritia (Arabica) eglantina perconfusa*

IREDALE, 1935

Austral. Zoologist 8 (2): 108

9. *Mauritia (Arabica) arabica brunnescens* CATE, 1964

The Veliger 7 (1): 24; plt. 5, figs. 3a, 3b

10. *Mauritia (Arabica) histrion westralis* (IREDALE, 1935)

Austral. Zoologist 8 (2): 108

*Talparia* TROSCHER, 1863

Das Gebiß der Schnecken 1: 204

> Type Species: *Cypraca talpa* LINNAEUS, 1758 <11. *Talparia talpa talpa* (LINNAEUS, 1758)

Systema Naturae, ed. 10: 720

*Cypraca* LINNAEUS, 1758

Systema Naturae, ed. 10: 718

(CIN.) MONTFORT, P. DENYS DE, 1810

Conchyl. Syst. 2: 630

> Type Species: *Cypraca tigris* LINNAEUS, 1758 <

## (Cypraca) LINNAEUS, 1758

12. *Cypraca (Cypraca) tigris pardalis* SHAW, 1795

Vivar. Natur. Misc. 6: plt. 193

- (*Lyncina*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea lynx* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 721
13. *Cypraea (Lyncina) argus argus* LINNAEUS, 1758  
Systema Naturae, ed. 10: 719
14. *Cypraea (Lyncina) lynx vanelli* LINNAEUS, 1758  
Systema Naturae, ed. 10: 720
15. *Cypraea (Lyncina) vitellus vitellus* LINNAEUS, 1758  
Systema Naturae, ed. 10: 721
16. *Cypraea (Lyncina) reevei* SOWERBY, 1832  
Conch. Illustr. (London) fig. 52
17. *Cypraea (Lyncina) carneola carneola* LINNAEUS, 1758  
Systema Naturae, ed. 10: 719
18. *Cypraea (Lyncina) leviathan gedlingae* CATE,  
subspec. nov.  
  
*Luria* JOUSSEAU, 1884  
Bull. Soc. Zool. France 9: 92  
(Naturaliste 1884: 414, nom. nud.)  
> Type Species: *Cypraea lurida* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 720  
  
(*Basilitronea*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 83  
> Type Species: *Cypraea isabella* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 722
19. *Luria (Basilitronea) isabella rumphii*  
SCHILDER & SCHILDER, 1938  
Proc. Malacol. Soc. London 23 (3-4): 177  
  
NARIINA SCHILDER, 1932  
Foss. Cat. 1: Animalia, pars 55, Cypraeacea. 149  
  
(*Pustulariini*) SCHILDER, 1932  
Foss. Cat. 1: Animalia, pars 55, Cypraeacea. 149  
  
*Pustularia* SWAINSON, 1840  
LARDNER's Encycl., p. 324  
  
(*Pustularia*) SWAINSON, 1840  
LARDNER's Encycl., p. 324  
> Type Species: *Cypraea cicercula* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 725
20. *Pustularia (Pustularia) cicercula cicercula*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 725
21. *Pustularia (Pustularia) globulus globulus*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 725  
  
Nariini SCHILDER, 1932  
Foss. Cat. 1: Animalia, pars 55, Cypraeacea: 159
- Monetaria* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea moneta* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723
- (*Ornamentaria*) SCHILDER &  
SCHILDER, 1936  
Proc. Zool. Soc. London 1936: 1120  
> Type Species: *Cypraea annulus* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723
22. *Monetaria (Ornamentaria) annulus annulus*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 723
- (*Monetaria*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205
23. *Monetaria (Monetaria) moneta rhomboides*  
SCHILDER & SCHILDER, 1933  
Zool. Meded. Leiden 16: 163
- Erosaria* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erosa* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723
- (*Ravitrona*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 82  
> Type Species: *Cypraea caputserpentis* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 720
24. *Erosaria (Ravitrona) labrolineata labrolineata*  
(GASKOIN, 1849)  
Proc. Zool. Soc. London for 1848: 97
25. *Erosaria (Ravitrona) cernica viridicolor* (CATE, 1962)  
The Veliger 4 (4): 175; pl. 40, figs. 1-9
26. *Erosaria (Ravitrona) helvola citrinicolor*  
IREDALE, 1935  
Austral. Zoologist 8 (2): 116
27. *Erosaria (Ravitrona) caputserpentis reticulum*  
(GMELIN, 1791)  
Systema Naturae, ed. 13: 3407
28. *Erosaria (Ravitrona) caputserpentis kenyonae*  
SCHILDER & SCHILDER, 1938  
Proc. Malac. Soc. London 23 (3): 136  
ibid. 3: 77, fig. 2
- (*Erosaria*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erosa* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723
29. *Erosaria (Erosaria) poraria poraria*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 724

30. *Erosaria (Erosaria) erosa purissima*  
(VREDENBURG, 1919)  
Journ. Asiat. Soc. Bengal 15: 143
31. *Erosaria (Erosaria) miliaris diversa* (KENYON, 1902)  
Journ. Conch. 10: 184
32. *Erosaria (Erosaria) turdus turdus* (LAMARCK, 1810)  
Ann. Mus. Hist. Nat. Paris 6: 74
- Staphylaea* JOUSSEAU, 1884  
Naturaliste 1884: 415
- (*Staphylaea*) JOUSSEAU, 1884  
> Type Species: *Cypraea staphylaea* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 725
33. *Staphylaea (Staphylaea) staphylaea staphylaea*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 725
34. *Staphylaea (Staphylaea) limacina facifer*  
(IREDALE, 1935)  
Austral. Zool. 8 (2): 119; plt. 8, fig. 6
- (*Nuclearia*) JOUSSEAU, 1884  
Bull. Soc. Zool. France 9: 98  
(Naturaliste 1884: 415, nom. nud.)  
> Type Species: *Cypraea nucleus* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 724
35. *Staphylaea (Nuclearia) nucleus nucleus*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 724
- Notocypraea* SCHILDER, 1927  
Arch. Naturgesch. 91/A 10: 110  
> Type species: *Cypraea piperita* GRAY, 1825 <  
Zool. Journ. 1: 498 (SOLANDER MS)
- (*Guttacypraea*) IREDALE, 1935  
Austral. Zool. 8 (2): 134  
> Type species: *Cypraea pulicaria* REEVE, 1846 <  
Conch. Icon. sp. 84, plt. 17, f. 84
36. *Notocypraea (Guttacypraea) pulicaria* (REEVE, 1846)  
Conch. Icon. 3: *Cypraea*, fig. 84
- (*Notocypraea*) SCHILDER, 1927  
> Type species: *Cypraea piperita* GRAY, 1825 <  
Zool. Journ. 1: 498 (SOLANDER MS)
37. *Notocypraea (Notocypraea) piperita* (GRAY, 1825)  
Zool. Journ. 1: 498 (SOLANDER MS)
- CYPRAEVULINAE SCHILDER, 1930  
Proc. Malacol. Soc. London 19: 120
- Erroneini SCHILDER, 1927  
Arch. Naturgesch. 91/A 10: 109
- Erronea* TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erronea* LINNAEUS, 1758 <
- (*Adusta*) JOUSSEAU, 1884  
Naturaliste 1884: 414  
> Type Species: *Cypraea adusta* LAMARCK, 1810 <  
Ann. Mus. Hist. Nat. 16: 92  
= *Cypraea onyx* LINNAEUS, 1758  
Systema Naturae, ed. 10: 722
38. *Erronea (Adusta) subviridis dorsalis*  
SCHILDER & SCHILDER, 1938  
Proc. Malacol. Soc. London 23 (3): 149
39. *Erronea (Adusta) pyriformis smithi* (SOWERBY, 1881)  
Proc. Zool. Soc. London for 1881: 638
40. *Erronea (Adusta) walkeri continens* (IREDALE, 1935)  
Austral. Zoologist 8 (2): 127
- (*Erronea*) TROSCHER, 1863  
Das Gebiß der Schnecken 1: 205  
> Type Species: *Cypraea erronea* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723
41. *Erronea (Erronea) ovum ovum* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3412
42. *Erronea (Erronea) erronea coxi* (BRAZIER, 1872)  
Proc. Zool. Soc. London for 1872: 617
43. *Erronea (Erronea) cylindrica sowerbyana*  
SCHILDER, 1932  
Foss. Cat. 1: Animalia, pars 55, Cypraeacea, 192
44. *Erronea (Erronea) caurica blaesa* IREDALE, 1939  
Austral. Zoologist 9 (3): 322
- (*Melicerona*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 83  
> Type Species: *Cypraea listeri* GRAY, 1824 <  
Zool. Journ. 1: 384  
= *Cypraea felina* GMELIN, 1791  
Systema Naturae, ed. 13: 3412
45. *Erronea (Melicerona) felina melvilli* (HIDALGO, 1906)  
Mem. Acad. Cienc. Madrid 25: 180
- Palmadusta* IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 82
- (*Palmadusta*) IREDALE, 1930  
> Type species: *Cypraea clandestina* LINNAEUS, 1767 <  
Systema Naturae, ed. 12: 1177
46. *Palmadusta (Palmadusta) asellus asellus*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 722

47. *Palmadusta (Palmadusta) clandestina clandestina*  
(LINNAEUS, 1767)  
Systema Naturae, ed. 12: 1177
48. *Palmadusta (Palmadusta) saulae crakei* CATE,  
subspec. nov.
49. *Palmadusta (Palmadusta) lutea bizonata*  
IREDALE, 1935  
Austral. Zoologist 8 (2): 126
50. *Palmadusta (Palmadusta) ziczac ziczac*  
(LINNAEUS, 1758)  
Systema Naturae, ed. 10: 722  
  
(*Purpuradusta*) SCHILDER, 1939  
Arch. Molluskenk. 71: 165  
> Type Species: *Cypraea fimbriata* GMELIN, 1791 <  
Systema Naturae, ed. 13: 3420
51. *Palmadusta (Purpuradusta) gracilis hilda*  
(IREDALE, 1939)  
Austral. Zoologist 9 (3): 312
52. *Palmadusta (Purpuradusta) fimbriata fimbriata*  
(GMELIN, 1791)  
Systema Naturae, ed. 13: 3420
53. *Palmadusta (Purpuradusta) hammondae dampierensis*  
SCHILDER & CERNOHORSKY, 1965  
The Veliger 7 (4): 225; plt. 29, figs. 1, 2  
  
*Bistolida* COSSMANN, 1920  
Rev. Crit. Paléozool. 24: 83  
> Type Species: *Cypraea stolidia* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 724  
  
(*Blasicrura*) IREDALE, 1930  
Mem. Queensld. Mus. 10 (1): 84  
> Type Species: *Cypraea rhinoceros* SOUVERBIE, 1865 <  
Journ. Conchyl. 13: 156; plt. 511  
= *Cypraea pallidula* GASKOIN, 1849  
Proc. Zool. Soc. London for 1848: 97 (Mar. '49)
54. *Bistolida (Blasicrura) quadrimaculata thielei*  
SCHILDER & SCHILDER, 1938  
Proc. Malacol. Soc. London 23 (3): 164
55. *Bistolida (Blasicrura) pallidula simulans*  
SCHILDER & SCHILDER, 1940  
Arch. Molluskenk. 72: 42
56. *Bistolida (Blasicrura) teres teres* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3405  
  
(*Derstolida*) IREDALE, 1935  
Austral. Zoologist 8 (2): 121  
> Type species: *Derstolida fluctuans* IREDALE, 1935 <  
Austral. Zoologist 8 (2): 121  
= *Cypraea brevidentata* SOWERBY, 1870  
Thesaur. Conch. (4): 11; fig. 325
57. *Bistolida (Derstolida) kieneri kieneri* (HIDALGO, 1906)  
Mem. Acad. Cienc. Madrid 25: 177
58. *Bistolida (Derstolida) hirundo cameroni*  
(IREDALE, 1939)  
Austral. Zool. 9 (3): 314; plt. 28, figs. 29-31
59. *Bistolida (Derstolida) ursellus ursellus* (GMELIN, 1791)  
Systema Naturae, ed. 13: 3411  
  
(*Bistolida*) COSSMANN, 1920  
Rev. Crit. Paléozool. 24: 83  
> Type Species: *Cypraea stolidia* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 724
60. *Bistolida (Bistolida) stolidia stolidia* (LINNAEUS, 1758)  
Systema Naturae, ed. 10: 724
61. *Bistolida (Bistolida) brevidentata* (SOWERBY, 1870)  
Thes. Conch. 4 (30): 11; plt. 30, figs. 325-326  
  
*Cribrarula* STRAND, 1929  
Acta Univ. Latv. 20: 8  
Syn.: *Cribraria* JOUSSEAUME, 1884 (twice preoccupied)  
Bull. Soc. Zool. France 9: 94  
> Type Species: *Cypraea cribraria* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723  
  
(*Ovatipsa*) IREDALE, 1931  
Rec. Austral. Mus. 18 (4): 219  
> Type Species: *Cypraea chinensis* GMELIN, 1791 <  
Systema Naturae, ed. 13: 3421
62. *Cribrarula (Ovatipsa) chinensis whitworthi*  
(CATE, 1964)  
The Veliger 7 (1): 20; plt. 5, figs. 2a, 2b  
  
(*Cribrarula*) STRAND, 1929  
> Type species: *Cypraea cribraria* LINNAEUS, 1758 <  
Systema Naturae, ed. 10: 723
63. *Cribrarula (Cribrarula) cribraria fallax*  
(E. A. SMITH, 1881)  
Ann. Mag. Nat. Hist., ser. 5, 8: 441

## DISCUSSION OF THE SPECIES

1. *Bernaya (Bernaya) catei* SCHILDER, 1963  
(Plate 21, Figure 1)

Locality: 163

(75.7 49.4 39.8 23 17)

CATE (1964, p. 21, no. 41)

This is a unique specimen, collected by a crayfisherman during the autumn of 1960, on a western beach of West Wallabi Island, Houtman Abrolhos Islands. The holotype is no. 12756 in the California Academy of Sciences, Department of Geology Type collection.

2. *Zoila friendii friendii* (GRAY, 1831)  
(Plate 24, Figure 12)

Localities: 18, 19, 25a, 28, 31, 35, 38, 54, 61a, 65, 83, 95, 98, 99, 118, 121a, 142, 143, 145, 172  
(66.7 35.3 27.3 22 6)

CATE (1964, p. 23, no. 47)

A specimen was collected in 10 feet of water on brown sponge,  $\frac{3}{4}$  mile off Sorrento Beach (145); collectors: B. R. Wilson and R. W. George; January 10, 1962; Cate coll. no. C 3404.

Four animals (2 of them subadult) were collected in 12 feet of water, living on orange sponge and *Pinna* shells; Cockburn, off Woodmans Point on the Parmelia Bank; collector: N. Mills, St. James Park, West Australia; February 1964; Cate coll. no. C 3405.

Much has been written about these shells, including the broad forms occurring in southwestern Australia east of Cape Leeuwin. However, it is interesting to note that HEDLEY (1916) did not mention this species while listing the mollusks of Western Australia.

In recent years a concerted effort has been made to ascertain the exact number of cypræid species now living in the West Australian coastal waters. Concurrently, a study of the ranges of their occurrence has been carried on as well. Pertinent to this report has been the consideration of this particular species and its development and living aspects, as we were able to find them. It was noted that *Zoila friendii* and its variations (excluding the subspecies *Z. f. thersites* (GASKOIN, 1849) and its color variant named *contraria* by IREDALE in 1935, appears to range from Esperance, in southwest Australia, northward along the west coast to an obscure point to the north of Sorrento Beach.

It should be noted that the largest specimens of *Zoila friendii friendii* (Cate coll. no. C 3404: 99.5 51.5 38.3 28 7) seem to be found in shallow water (10 feet) about  $\frac{3}{4}$  mile offshore at Sorrento Beach. The specimens exhibit no hint of change in shell form at this locality where the species approaches the northern end of its range. Shells here possess the typical rudimentary abapical columellar teeth, which are large and stubby.

Recent discovery has brought to light a new cowrie form living in the deep waters west of Shark Bay. In 1965 the brothers William and Wilfred Poole, fishing out of Fremantle, were trawling in the area west of the Dorre-Bernier-Koks Island chain (25° 00' S Long.; 113° 08' E Lat.), approximately 40 miles west of Carnarvon. Along with the outer peninsula of Denham Sound and Dirk Hartog Island, these islands form the western perimeter of Shark Bay. It is said the Poole brothers found 10 shells in about 60 fathoms of water. It is further believed other specimens have since been taken from this area. WILSON

& SUMMERS (1966) list specimens as having been taken "off Geraldton," and from False Entrance (False Entrance is 12 miles south of Steep Point, which marks the southern shoreline of South Passage; South Passage is the waterway separating the mainland and Dirk Hartog Island).

On examination, the Dorre-Bernier-Koks Island shells appear to be morphologically distinct from those found at Sorrento Beach. I have compared them with 31 shells in my collection, among which are specimens representing most of the known localities for this species on the southwest coast and east into South Australia. In addition, I was able to examine the shells in both the South Australian Museum, Adelaide, and the West Australian Museum, Perth. Except for the obvious morphological change as observed in the South Australian *Zoila friendii vercoi* (Plate 23, Figure 11), the species elsewhere was noteworthy for its normally uniform shell shape and apertural count and arrangement. Even so, despite this broader shell growth in the south coast shells, they are all typical *Z. f. friendii* in general overall shape and dentition.

The Dorre-Bernier-Koks Island shells, on the other hand, are not typical, in my opinion. I have examined 6 of these shells and find them to be distinctly different from any other allopatric form in the *Zoila friendii* species complex. The differences will be discussed further in the following subspecies.

3. *Zoila friendii jeanianana* CATE, subsp. nov.  
(Plate 24, Figure 13)

Localities: 62a, 68, 71a, 83

Shell large, strong, lightweight, humped, globular-ovate; base sloping inward from outer margins; lip base flat, columellar base perceptibly convex; terminals prominent, thin-sided, sharply edged, and more thickly and roundly formed in front; margins acutely angled, only thinly caloused, vertically broad, with granular texture; aperture straight, curving abruptly left adapically; teeth numerous, medium in length, strong, well defined, particularly on abaxial margin of fossula; fossula deep, without denticles, milk-white in color; primary shell color on dorsum light grey, with approximately three narrow white transverse bands, all of which can be seen through an irregular outer layer of light chestnut-brown, which becomes an irregular, darker color immediately above the lateral margin; broad margins are off-white, with faint touches of beige, loosely marked otherwise with large, dark brown spots; base dark chestnut-brown, with same coloring extending over half the length of teeth and interstices; other half of teeth and interstices off-white.

*Zoila friendii jeanianana* differs from *Z. f. friendii* (GRAY, 1831) in being a shorter, broader, more humped, more globular-ovate shell; in having a full complement of



Figure 1  
*Bernaya catei* SCHILDER, 1963 (holotype) x 1

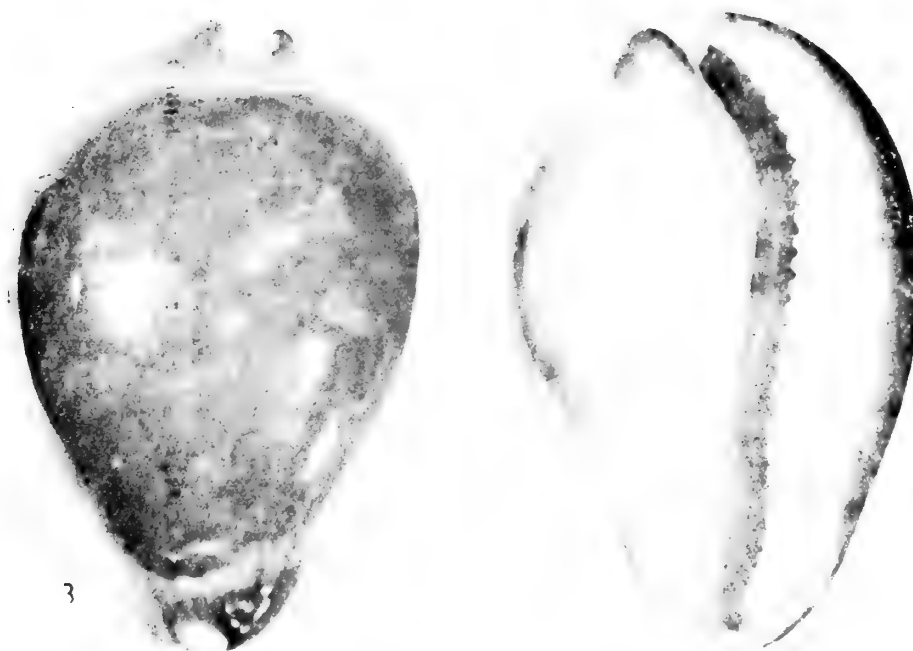


Figure 2  
*Zoila episema* IREDALE, 1939 (holotype) x 1  
= *Zoila venusta* (SOWERBY, 1846)



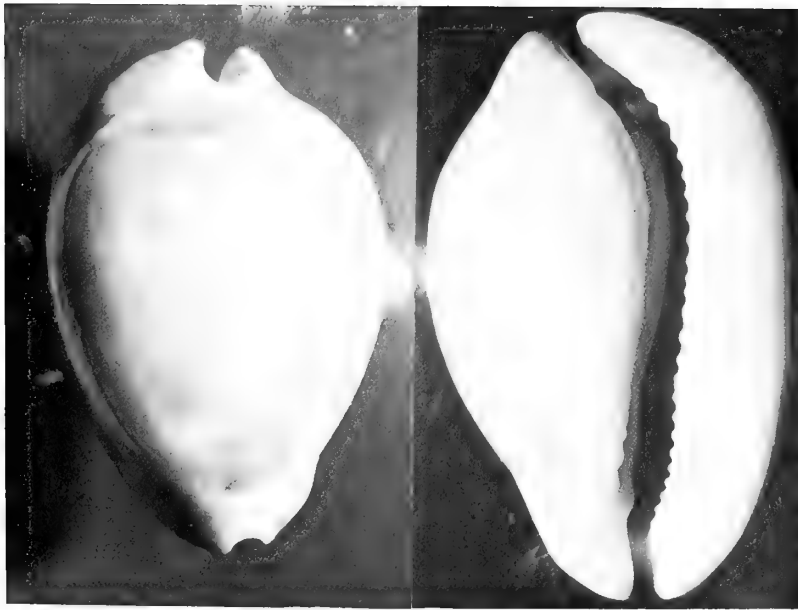


Figure 3  
*Zoila venusta* (SOWERBY, 1846) x 1  
(Color Variant)

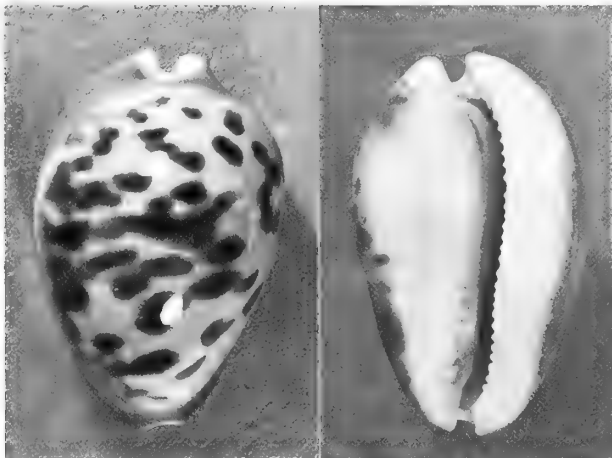


Figure 4  
*Zoila venusta* (SOWERBY, 1846) x  $\frac{1}{2}$   
Geographe Bay

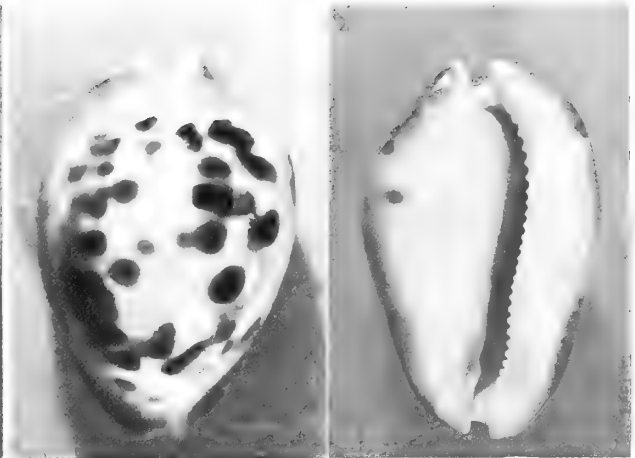


Figure 5  
*Zoila venusta* (SOWERBY, 1846) x  $\frac{2}{3}$   
Binningup



teeth on both lip and columella; in having broad off-white lateral margins with large brown spots; in having, in some specimens, an abruptly curved adapical terminal opening; in having an unusual color pattern in the dorsal nacre.

*Zoila friendii jeaniana* differs from *Z. friendii thersites* (GASKOIN, 1849), a subspecies restricted almost entirely to South Australia, by a more pyriform, globular-ovate shell; by the base and part of the teeth being all brown; by the broad off-white spotted margins; and by the more numerous teeth on the apertural edges.

The holotype will be deposited in the West Australian Museum, where it will bear the catalogue number WAM 1320-67. This new form of *Zoila friendii* has been named in honor of Mrs. Jean Cate, Los Angeles, whose contributions to malacology and its literature are well known.

A further consideration of consequence is a geographical separation between the living areas of the new form and the nominate species, *Zoila friendii friendii* from Sorrento Beach of approximately 500 miles. It seems probable that somewhere between these two localities there may be an overlapping in the ranges of the two subspecies. This possibility can be seen in the specimen listed

as hypotype no. 5 (85.8 52.0 43.0 31 29) from Green Head, which is about 100 miles north of Sorrento Beach. It possesses some morphological affinity to *Z. f. friendii*, yet at the same time displaying more of the shell characters of *Z. f. jeaniana*, suggesting that the Green Head area could be the point of change in the species.

The specimen from Green Head seems to be analogous to the pale color forms of *Zoila venusta* and *Z. friendii thersites* (the color form of the latter subspecies known as "*Z. contraria*" IREDALE, 1935). The pale form of *Z. f. jeaniana* is a pale off-white with pale beige, irregular markings, shading to a more intense pale orange color on either side of both terminals; the base is milk-white, and the teeth are numerous.

Since having completed this report 3 additional specimens have come to hand; one was trawled in deep water off Quobba Point. Jack Allen, a fisherman, of Babbage Island off Carnarvon, was the collector (June 1967), and the specimen was a gift to me from Mr. George Barker of Geraldton. This shell (68.5 45.5 38.3 32 27), Cate coll. no. C 3504, will be identified as hypotype no. 2. The other two animals were trawled at 30 fathoms, 4 miles west of Quobba Point, July 1, 1967 (collector not deter-

Table 1

Measurements (in millimeters) and other data, for comparison								
Species	Length	Width	Height	Lip Teeth	Col. Teeth	Locality	Specimen Ident.	Disposition of Shells
<i>Zoila friendii jeaniana</i>								
subspec. nov.	75.7	50.0	40.7	33	29	83	Holotype	West Australian Museum no. WAM 1320-67
(subadult)	75.6	50.5	41.4	32	17+	83	Paratype 1	Ned Harrold coll., Perth
	67.4	45.3	39.0	28	26	83	Paratype 2	Anthony Kalnins, Mayfields, W. A.
	73.1	47.6	39.0	28	22	83	Paratype 3	Theodore Gurr, Carlisle, W. A.
	69.3	45.2	36.1	28	21	83	Paratype 4	Theodore Gurr, Carlisle, W. A.
	85.8	52.0	43.0	31	29	71a	Hypotype 1	Ned Harrold, Victoria Park, W. A.
<i>Zoila friendii friendii</i>								
	99.3	51.6	38.3	27	7	145	Hypotype 1	Cate coll. no. C 3404
	70.9	41.0	34.0	27	7	172	Hypotype 2	Cate coll. no. C 3497
	72.4	37.4	29.5	21	6	172	Hypotype 3	Cate coll. no. C 3497
	73.8	38.6	31.1	25	8	61a	Hypotype 4	Cate coll. no. C 1712
	73.4	38.0	31.0	27	7	61a	Hypotype 5	Cate coll. no. C 1712
	80.0	40.0	31.0	25	7	121a	Hypotype 6	Cate coll. no. C 3498
	78.9	41.8	34.5	27	12	95	Hypotype 7	Cate coll. no. C 1711
	68.5	36.0	28.6	24	11	95	Hypotype 8	Cate coll. no. C 1711
	92.6	49.9	37.0	30	10	25a	Hypotype 9	Cate coll. no. C 3499
	78.0	41.0	32.8	25	9	25a	Hypotype 10	Cate coll. no. C 3499
<i>Zoila friendii vercoi</i>								
	83.3	53.1	39.0	26	10	2a	Hypotype 1	Cate coll. no. C 1706
	76.8	49.2	35.4	24	9	59a	Hypotype 2	Cate coll. no. C 3500
	73.8	44.0	34.3	22	5	59a	Hypotype 3	Cate coll. no. C 3501

mined). These are from the Ned Harrold collection, Victoria Park, West Australia. They are the hypotypes no. 3 (68.0 46.8 35.7 29 27) and no. 4 (63.9 42.0 33.1 33 26).

The 9 shells of this new taxon that I have seen give a convincing indication that it should be considered a distinct species rather than only a subspecies; but until we know more about the animal's soft parts and radula and its still unknown habitat and geographical distribution, it seems best to take a conservative approach and consider it a subspecies of *Zoila friendii*.

4. *Zoila venusta* (SOWERBY, 1846)

(Plate 21 Figure 2 to Plate 23, Figure 10)

Syn.: *C. venusta* var. SOWERBY, 1846 = *Cypraea thatcheri* COX, 1869

*Z. episema* IREDALE, 1939

*Z. sorrentensis* SCHILDER, 1963

Localities: 14, 18, 20, 36, 39, 40, 42, 52, 65, 67, 71, 78, 79, 88, 97, 101, 145, 154, 163  
(77.7 49.5 21.7 25 9)

CATE (1964, p. 22, no. 42)

Three specimens were found in 8 to 30 feet of water at Sorrento Beach (145), living on green algae under reef ledges, by N. Mills, St. James Park, West Australia in March 1963; Cate coll. no. C 3409. Another specimen, Cate coll. no. C 3410, was removed from a crayfish pot set in 19 fathoms, 5 miles west of Rat Island (130) by Joseph Burton, Geraldton, in August 1964. Still another specimen, Cate coll. no. C 3406, was collected by fisherman Gordon McAulley, Geraldton, in January 1965 from a crayfish pot set in 28 fathoms about 22 miles west of Dongara (52). Two specimens were collected in 20 feet of water with SCUBA gear, 12 miles south of Mandurah (97) in 1961; Cate coll. no. C 3408. One animal was found living in a marine cave at 10 fathoms off Binningup (20) in January 1964; ex. Edward Nickles, Mandurah; Cate coll. no. 3194. Yet another animal was found on the ceiling in a limestone cave in 30 feet of water at Rottnest Island (131), adjacent to the wreck of the ship *Macedon*; kelp and other seaweed was present; the collector was William Hill, Rottnest Island; October 1963; Cate coll. no. C 3023.

In CATE (1962), after examination of many specimens of *Zoila venusta*, and observing the gradual change in shell size and structure throughout its range, I was convinced that there was but one species involved, but with different local ecological variations to be seen at progressive localities. Shells in my collection, and those recently seen in the South Australian Museum, the West Australian Museum, and in numerous private collections (one of which contained approximately 40 specimens from the Sorrento Beach-Reef area!) in West Australia, appear

very definitely to have close affinity, all seeming to possess a common species character. The morphological change commences immediately, starting at Geographe Bay (see Plate 22, Figure 4), becoming obvious in the area of Binningup (Plate 22, Figure 5), then Mandurah (Plate 23, Figure 6), Rottnest Island (Plate 23, Figure 7), and attaining the greatest change in the waters just north of Fremantle, Sorrento Beach (Plate 23, Figure 8) to Jurien Bay (Plate 23, Figure 9), then receding back to "normal" size and shape at Dongara, Geraldton, Abrolhos Islands (Plate 23, Figure 10), and north to the Dampier Islands.

The point of recession from the Sorrento Beach-Reef area variation seems to commence in the waters of Jurien Bay, and noticeably so at Dongara. It is true, the shells from north of Geraldton appear more bulbous, darker in color, and with a pinched, often-times narrower base and aperture (see Plate 23, Figure 10). It would seem that none of the various changes in the shell, including the pale pinkish-beige to off-white variants (Plate 22, Figure 3) collected at Cervantes Island and Geographe Bay, are sufficient to justify considering them as more than localized variants. This appears to be particularly true because of the continuous range of the species, with no distinct natural barriers to interbreeding.

I have examined the pale colored shell variants collected at Cervantes Island (1) and Geographe Bay (3), one of these 3 in my own collection (no. C 3502: 73.2 48.3 38.8 25 13) that was trawled in 40 fathoms of water in 1950 by an unidentified Dutch fisherman. Mr. A. R. Whitworth obtained this shell from Arthur Bassett of Denham, Shark Bay, in 1960. The Cervantes specimen is in the Ned Harrold collection, Victoria Park; the other 2 of the 3 specimens from Geographe Bay are in the George Barker collection, Geraldton, and the Trevor Sutcliffe collection (see SCHILDER, 1966), Mount Yokine, Western Australia.

5. *Zoila marginata* (GASKOIN, 1849)

(Plate 24, Figure 14)

Localities: 2a, 3, 8, 30a, 34a, 36, 52, 53, 57, 67, 68, 71, 71b, 78, 83, 89, 118, 147, 151, 152, 162, 163, 180  
(51.8 31.0 24.9 27 22)

CATE (1964, p. 23, no. 49)

A specimen was removed from a crayfish pot set at 28 fathoms 7 miles south of Long Island (94), ex Max Cramer, Geraldton; October 1953; Cate coll. no. C 2516. Another animal was removed from a crayfish pot set in 22 fathoms off Dongara (52) in September 1963. The collector was fisherman F. I. "Sonny" Healy, Dongara and the shell is in his collection. Still another specimen was found in a crayfish pot that had been set in 20 fathoms off Leander Reef (53), WSW of Dongara, collected by fisherman Edward Scabrook, Fisheries Department, Perth.

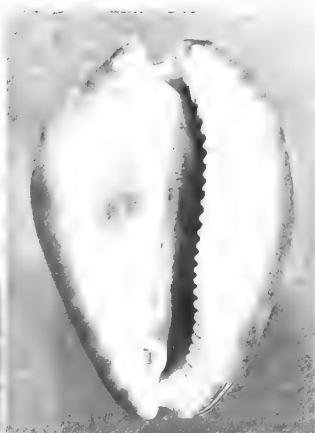
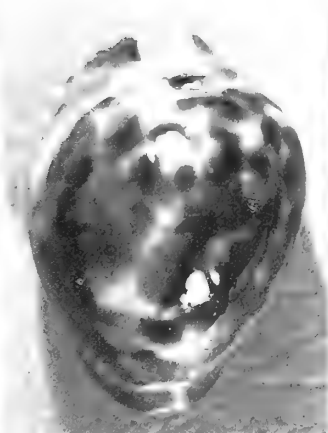
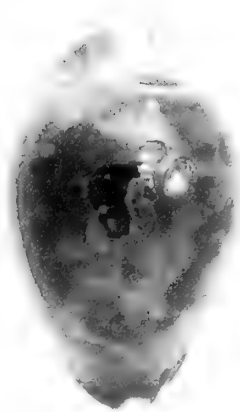


Figure 6

*Zoila venusta* (SOWERBY, 1846)  $\times \frac{2}{3}$   
Mandurah

Figure 7

*Zoila venusta* (SOWERBY, 1846)  $\times \frac{2}{3}$   
Rottneest Island



Figure 8

*Zoila venusta* (SOWERBY, 1846)  $\times \frac{2}{3}$   
Sorrento Reef

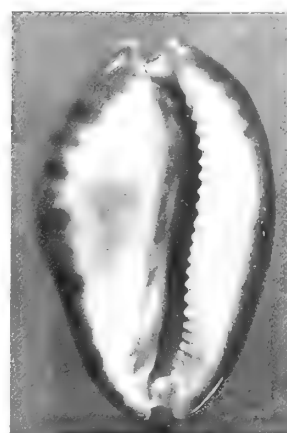
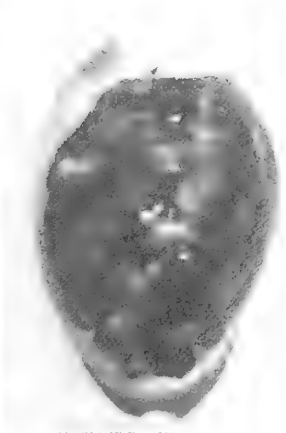


Figure 9

*Zoila venusta* (SOWERBY, 1846)  $\times \frac{2}{3}$   
Jurien Bay

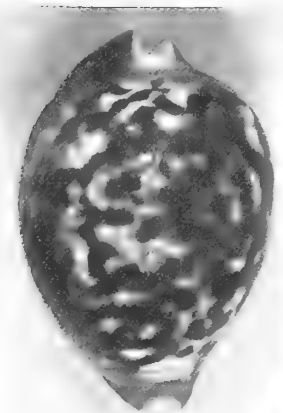


Figure 10

*Zoila venusta* (SOWERBY, 1846)  $\times \frac{1}{2}$   
Rat Island, Abrolhos



Figure 11

*Zoila friendii vercoi* SCHILDER, 1930  $\times \frac{1}{2}$   
Albany, South Australia





Figure 12  
*Zoila friendii friendii* (GRAY, 1831)  $\times \frac{1}{2}$   
Geographe Bay



Figure 13  
*Zoila friendii jeaniana* subsp. nov.,  $\times \frac{1}{2}$   
Koks Island, West Australia

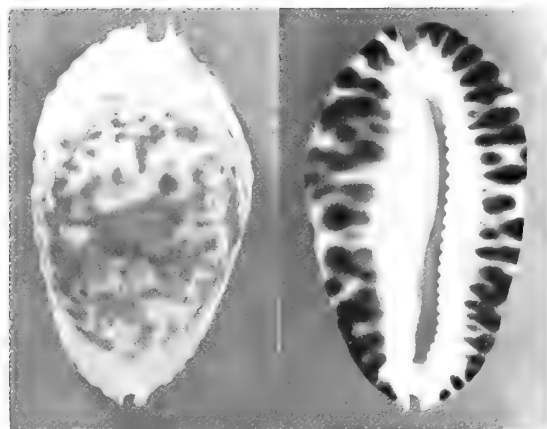


Figure 14  
*Zoila marginata* (GASKOIN, 1849)  $\times 1$   
Long Island, Abrolhos

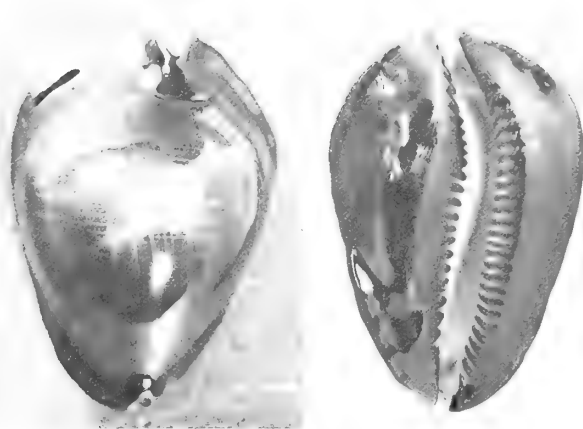


Figure 15  
*Zoila rosselli* COTTON, 1948  $\times 1$   
Rat Island, Abrolhos

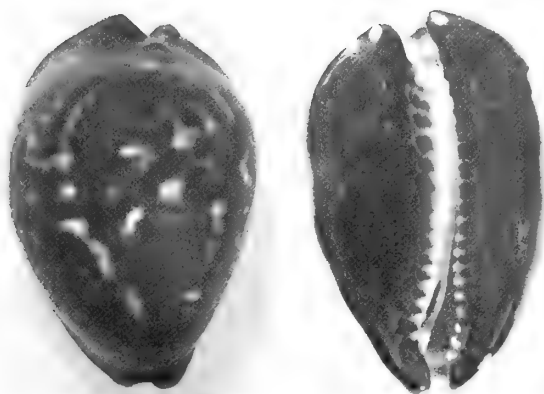


Figure 16  
*Zoila decipiens* (E. A. SMITH, 1880)  $\times 1$   
Gourdon Bay, West Australia

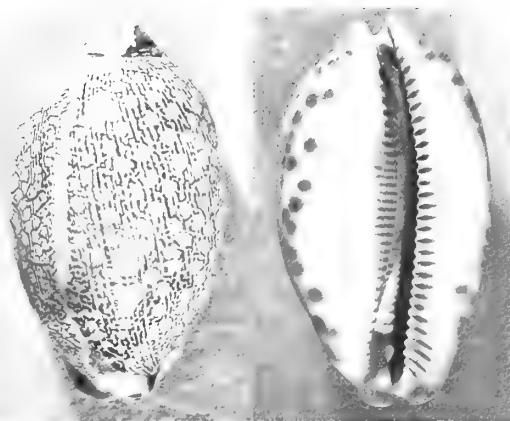


Figure 17  
*Mauritia eglantina perconfusa* IREDALE, 1935  $\times \frac{2}{3}$   
Roebuck Bay, West Australia



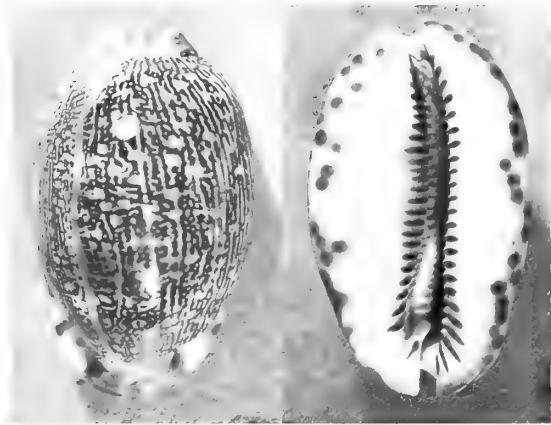


Figure 18  
*Mauritia arabica brunnescens* CATE, 1964  $\times \frac{2}{3}$   
Roebuck Bay, West Australia

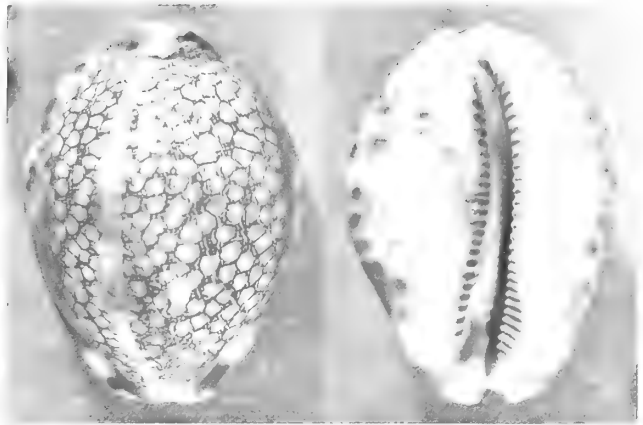


Figure 19  
*Mauritia histrio westralis* (IREDALE, 1935)  $\times \frac{2}{3}$   
Roebuck Bay, West Australia

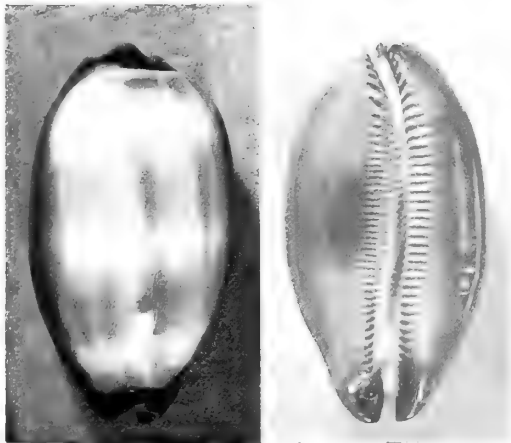


Figure 20  
*Talparia talpa talpa* (LINNAEUS, 1758)  $\times \frac{2}{3}$   
Yardie Creek, North West Cape



Figure 21  
*Cypraea tigris pardalis* SHAW, 1795  $\times \frac{1}{2}$   
Roebuck Bay, West Australia

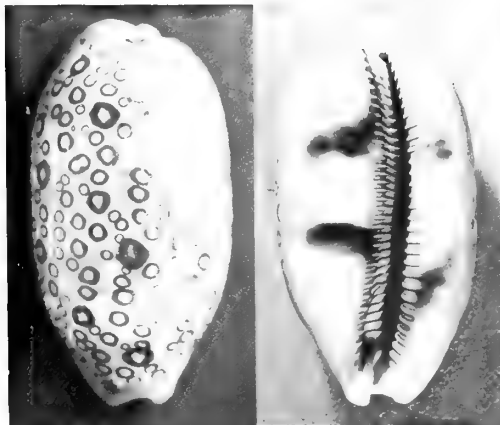


Figure 22  
*Cypraea argus argus* LINNAEUS, 1758  $\times \frac{2}{3}$   
Point Maud

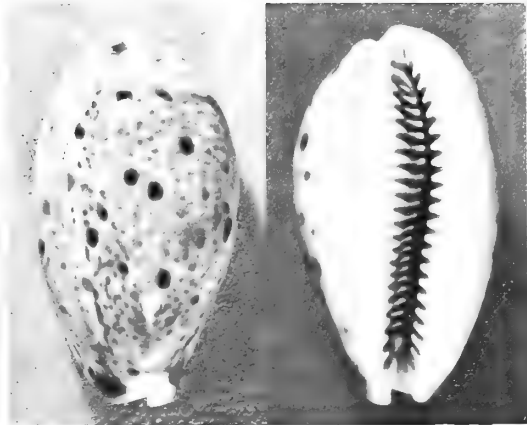


Figure 23  
*Cypraea lynx vanelli* LINNAEUS, 1758  $\times 1$   
Vlaming Head, North West Cape



The shell is in the Cate collection, no. C 3400.

Another specimen was found in a crayfish pot set at 24 fathoms, 3 miles east of Rat Island in Good Friday Bay (71), Abrolhos Islands; collector: Alec Gilbertson, Geraldton, 21 November 1957; Cate coll. no. C 3395. A broken shell and a subadult shell, both without animal, were dredged from 28 fathoms, 16 miles WSW of Geraldton in November 1964 by Alec Gilbertson; the shells are in his collection.

In comparing the shells from Western Australia with those from South Australia, one notices that the southern specimens are more frail, with lighter brown spots more sparsely arranged in fewer and more shallow concavities; another noticeable feature is the pale pinkish color within the shells themselves, while all those I have seen from western waters have white interiors. Additionally, the base of the southern shells is flat, while the west coast shells appear to have a more swollen, convex base.

In 1961 I referred to *Zoila marginata* (Cate coll. no. C 906), citing Albany, Southwest Australia as its locality. At that time the knowledge concerning this species was limited to that of the holotype in the British Museum, whose original label shows "New Holland" as its source. Specimens that came to light after 1961 were all from the area west of Geraldton, West Australia. The Albany locality for the specimen mentioned above, therefore, seemed to be doubtful. This was especially true with no collecting stations then known south of the Abrolhos Islands (see Map). In October 1966, Dr. Helene M. Laws of the South Australian Museum mentioned to me that 3 specimens of *Z. marginata* had recently been collected in South Australian waters: at Cape Jarvis, Taylor Island, and at a station near Grindel Island. A detailed report is now documented in LAWS (1966). It is reasonable to surmise, therefore, that Albany may have been the home port of an early fishing fleet and that one of the fishermen may have taken the hypotype in a trawl or crayfish pot.

6. *Zoila rosselli* COTTON, 1948  
(Plate 24, Figure 15)

Localities: 19, 36, 42, 48, 52, 53, 75, 87, 90, 104, 118, 163, 170  
(55.4 37.7 26.6 29 25)

CATE (1964, p. 22, no. 45)

One of several specimens was dredged in mud and coral rubble adjacent to North Wharf, Fremantle (61). This is one of the Rossell paratypes (Cate coll. no. C 1351). A specimen was found in approximately 6 inches of water, crawling on algae-covered substrate at the southwest corner of Wooded Island (170), Abrolhos Islands, in 1963; ex A. R. Whitworth, Geraldton; Cate coll. no.

C 3288. An animal was removed from a crayfish pot set in 18 fathoms at Leander Reef (53), off Dongara, in the spring of 1965; collector was F. I. Healy, Dongara; Cate coll. no. C 3290. Another specimen was removed from a crayfish pot set in 22 fathoms, 25 miles southwest of Dongara. The shell is only half-grown, with a razor-edge thin lip; this is the only bulla-stage specimen of *Zoila rosselli* that I have seen; in this form it is indeed rare; the collector was F. I. Healy of Dongara; January 3, 1965; Cate coll. no. C 3289. An additional specimen was removed from a crayfish pot at Ledge Point (87), set in 30 fathoms in July, 1965; ex A. R. Whitworth, Geraldton; Cate coll. no. C3401. One animal was collected intertidally on algae-covered coral at the west end of Rat Island (130), Abrolhos Islands; ex A. R. Whitworth, Geraldton, 1965; Cate coll. no. C 3402. The most recently collected specimen was removed from a crayfish pot set in 80 fathoms (this is exceptionally deep for craypots) off the southwest bank at North Island (104a). It was adhering to animal bait (cow hock); William Thompson, Geraldton; April 1967.

7. *Zoila decipiens* (E. A. SMITH, 1880)  
(Plate 24, Figure 16)

Localities: 7, 29, 44, 60, 80, 119  
(55.5 37.2 33.7 22 18)

CATE (1964, p. 22, no. 45)

Locality records of the South Australian Museum list these additional collecting stations for *Zoila decipiens*: Cossack, near Port Walcott; 'King (George) Sound'; and Fremantle (H. Rossell, So. Austral. Mus. no. 11636). This latter locality is considerably farther south than the hitherto southern-most authenticated record known to me, namely, Learmouth at Wapet Creek in Exmouth Gulf (86). This shell was picked up on the beach after Cyclone "Katie," Easter Sunday 1964 by Mrs. Molly Gedling, one of the keepers of the Vlaming Head Light; Cate coll. no. C 3112. Otherwise, the most northern record we have been able to authenticate is a specimen collected at Wyndham, Cambridge Gulf, 250 miles south of Darwin (44); Cate coll. no. C 3399.

8. *Mauritia (Arabica) eglantina perconfusa*  
IREDALE, 1935

(Plate 24, Figure 17)

Localities: 10, 37, 43, 46, 47, 49, 54, 93, 98, 108, 111, 117, 119, 142, 150, 153, 155, 163, 176, 178  
(62.2 37.2 30.5 35 31)

CATE (1964, p. 24, no. 53)

[For a discussion of this species see: CATE, 1964]

9. *Mauritia (Arabica) arabica brunnescens* CATE, 1964  
(Plate 25, Figure 18)

Localities: 10, 15, 108, 176  
(61.7 36.7 30.1 28 24)

CATE (1964, p. 24, no. 54)

[For a discussion of this species see: CATE, 1964]

10. *Mauritia (Arabica) histrio westralis* (IREDALE, 1935)  
(Plate 25, Figure 19)

Localities: 24, 45, 60, 115  
(70.2 45.9 35.2 30 24)

CATE (1964, p. 25, no. 55)

WEAVER (1960) listed "*Mauritia maculifera* SCHILDER," beach collected on the east side of Long Island. This collecting station is just north of the land end of North West Cape on the outer perimeter of Exmouth Gulf. Based on our present knowledge of the West Australian cowries, and upon a subsequent personal conversation with Mr. Weaver, it seems likely the shells found were specimens of *M. histrio westralis*. There can be little doubt of the close relationship between these two species, but one can observe the smaller, shorter, and more numerous teeth and lack of the central, though diffused, coloring on the base, both of which clearly distinguish this western species.

11. *Talparia talpa talpa* (LINNAEUS, 1758)  
(Plate 25, Figure 20)

Localities: 60, 64, 153, 159, 176  
(68.0 37.9 33.3 44 44)

CATE (1964, p. 24, no. 52)

[For a discussion of this species see: CATE, 1964]

12. *Cypraea (Cypraea) tigris pardalis* SHAW, 1795  
(Plate 25, Figure 21)

Localities: 2, 68, 102, 108, 109, 114, 119, 124, 142, 162, 163, 170, 176  
(89.1 60.4 47.0 27 22)

CATE (1964, p. 26, no. 56)

A specimen (111.2 73.2 57.1 24 24) was found in approximately one foot of water on a portion of the reef extending out from the southwest shore of West Wallabi Island (163). It was collected by William McWade of Geraldton in July 1966; Cate coll. no. C 3417. Another specimen was found at Wooded Island (170), Abrolhos Islands, in 3 feet of water on algae-covered coral, by A. R. Whitworth, Geraldton in the spring of 1965; Cate coll. no. C 3418.

13. *Cypraea (Lyncina) argus argus* LINNAEUS, 1758  
(Plate 25, Figure 22)

Localities: 44, 69, 70, 98, 106, 109, 159, 160, 176  
(91.3 49.6 37.7 43 40)

CATE (1964, p. 24, no. 51)

A specimen was found by Mrs. Alan Nicol, Carnarvon, at Glenroy (69), 10 miles south of Onslow, in the beach drift; Cate coll. no. C 3396. In June 1964, a dead, broken shell was found in a tide pool 4 miles southwest of Vlaming Head Light (160), North West Cape, by Mrs. Molly Gedling; Cate coll. no. C 3053. Another specimen was found on the beach just south of Vlaming Head Light after a heavy southwest wind storm in August, 1964, also by Mrs. Gedling; Cate coll. no. C 3107.

14. *Cypraea (Lyncina) lynx vanelli* LINNAEUS, 1758  
(Plate 25, Figure 23)

Localities: 2, 15, 24, 37, 43, 44, 48, 59, 63, 86, 108, 114, 117, 119, 142, 150, 153, 163, 176, 178  
(40.7 24.1 20.6 26 19)

CATE (1964, p. 26, no. 57)

The shells of this species exhibit great variation in size, color, and shape, wherever it occurs. In some localities this variability is more pronounced than in others; the base, teeth, aperture, and interstices are the most constant shell characters.

15. *Cypraea (Lyncina) vitellus vitellus* LINNAEUS, 1758  
(Plate 26, Figure 24)

Localities: 2, 6, 8, 10, 16, 35, 47, 52, 57, 62, 68, 72, 75, 86, 89, 90, 94, 100, 104, 108, 110, 111, 114, 119, 141, 150, 153, 163, 170, 176, 178  
(49.7 31.4 27.8 26 23)

CATE (1964, p. 26, no. 58)

[For a discussion of this species see: CATE, 1964]

16. *Cypraea (Lyncina) reevei* SOWERBY, 1832  
(Plate 26, Figure 25)

Localities: 18, 20, 32, 36, 39, 40, 52, 53, 68, 88, 156, 163, 175  
(34.2 21.5 18.7 29 22)

CATE (1964, p. 26, no. 59)

A specimen was found in a crayfish pot set in 15 fathoms adjacent to Turtle Dove Shoal (156), WSW of Dongara, ex James Seabrook, Fisheries vessel *Lancelin*, Perth, March 1964; Cate coll. no. C 3397. Another animal was collected intertidally under a rock on the north approach to Cape Naturaliste; B. R. Wilson collected it in November 1965; Cate coll. no. C 3398.

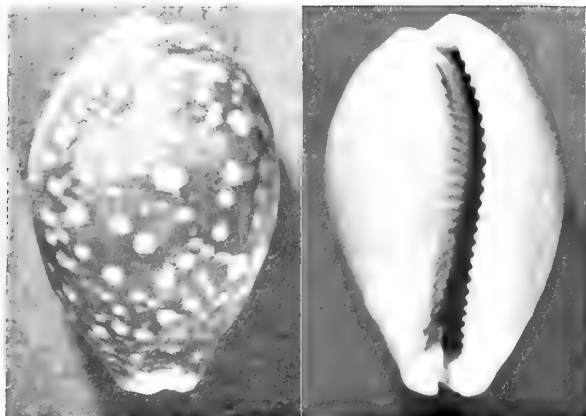


Figure 24  
*Cypraea vitellus vitellus* LINNAEUS, 1758  $\times \frac{3}{4}$   
Broome, Roebuck Bay

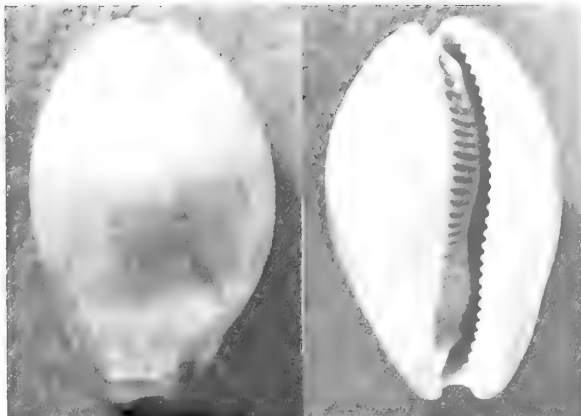


Figure 25  
*Cypraea reevei* SOWERBY, 1832  $\times 2$   
[normal form] Geographe Bay

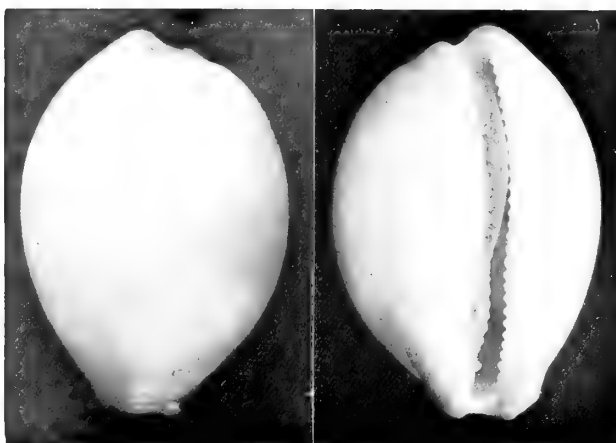


Figure 26  
*Cypraea reevei* SOWERBY, 1832  $\times \frac{1}{2}$   
[spherical form] Dongara

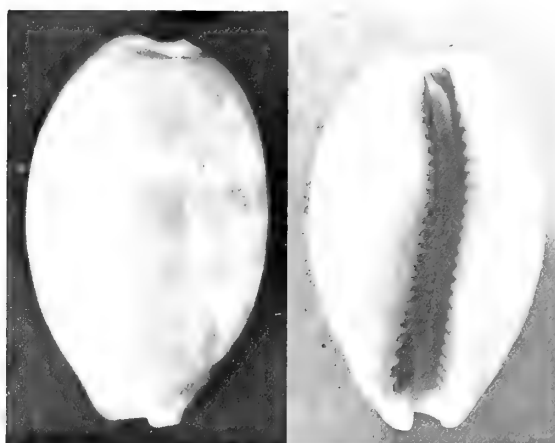


Figure 27  
*Cypraea carneola carneola* LINNAEUS, 1758  $\times \frac{2}{3}$   
Vlaming Head, North West Cape



Figure 28  
*Cypraea leviathan gedlingae* subsp. nov.  $\times \frac{1}{2}$   
Five Mile Beach, North West Cape

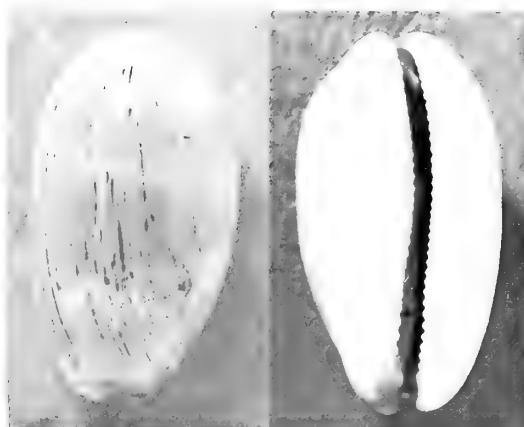


Figure 29  
*Luria isabella rumphii* SCHILDER & SCHILDER, 1938  $\times \frac{2}{3}$   
Broome, Roebuck Bay



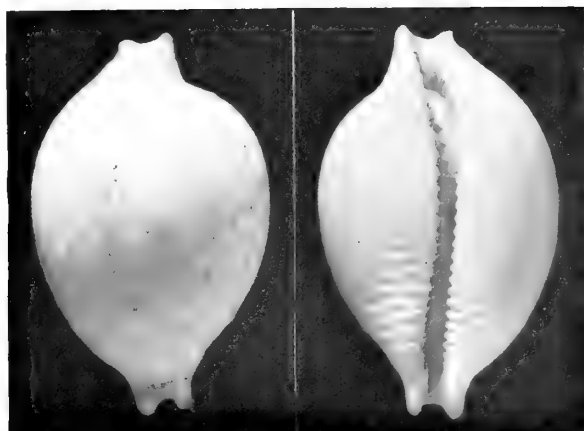


Figure 30  
*Pustularia cicercula cicercula* (LINNAEUS, 1758) x 3  
Vlaming Head, North West Cape

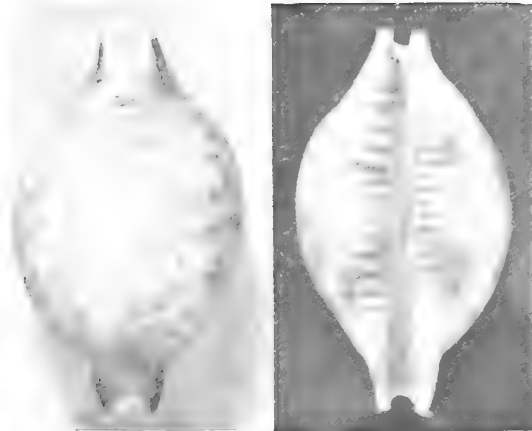


Figure 31  
*Pustularia globulus globulus* (LINNAEUS, 1758) x 3  
Yardie Creek, North West Cape

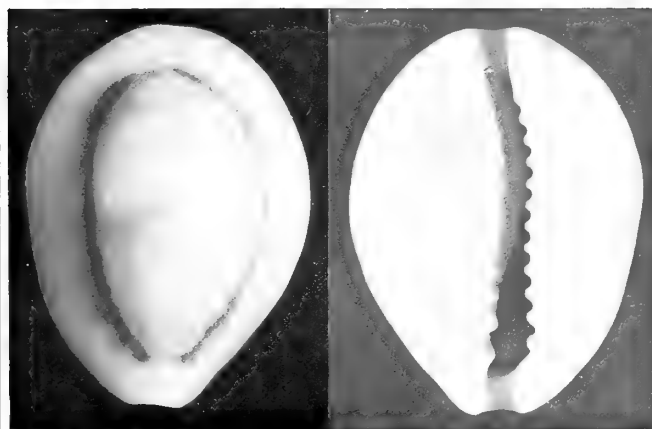


Figure 32  
*Monetaria annulus annulus* (LINNAEUS, 1758) x 2  
Vlaming Head, North West Cape

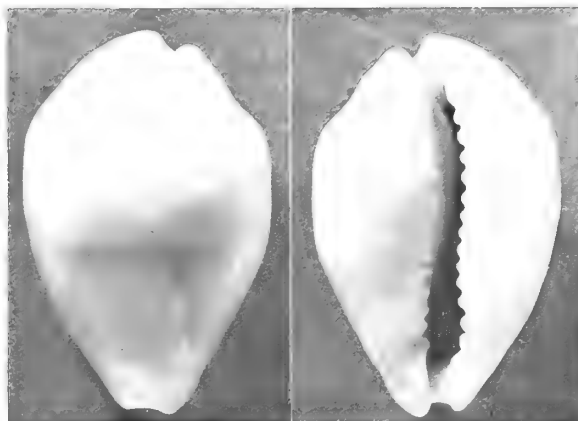


Figure 33  
*Monetaria moneta rhomboides* SCHILDER & SCHILDER, 1933 x 1/2  
Broome, Roebuck Bay

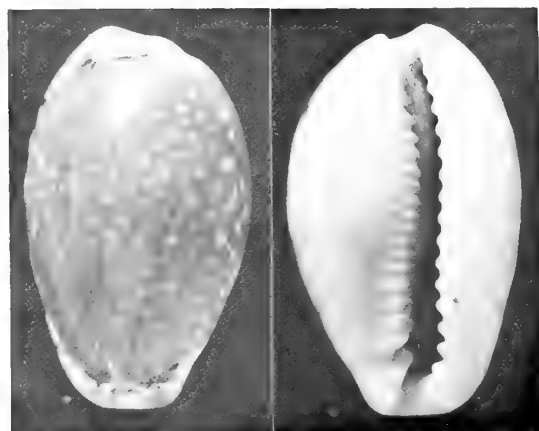


Figure 34  
*Erosaria l. labrolineata* (GASKOIN, 1849) x 3  
Exmouth Gulf

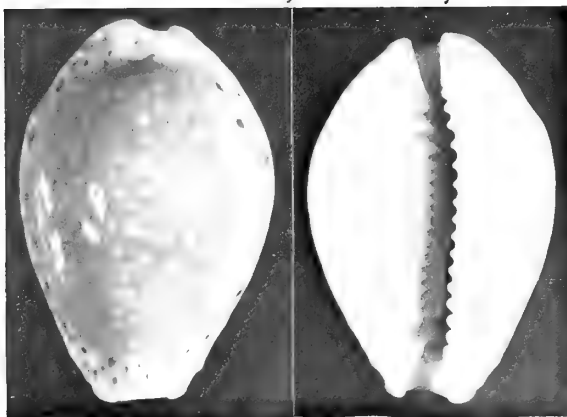


Figure 35  
*Erosaria cernica viridicolor* (CATE, 1962) x 2  
Vlaming Head, North West Cape



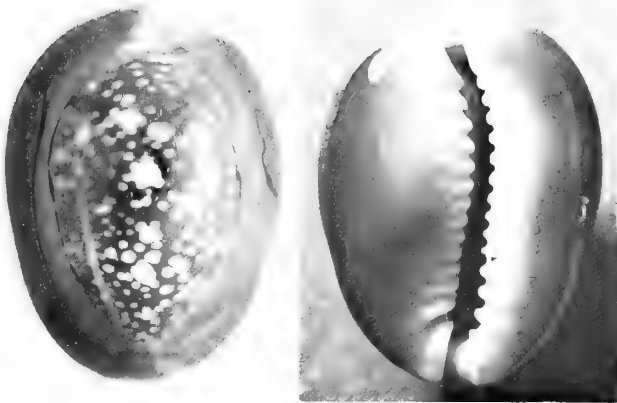


Figure 36  
*Erosaria caputserpentis reticulum* (GMELIN, 1791)  $\times \frac{2}{3}$   
Yardie Creek, North West Cape

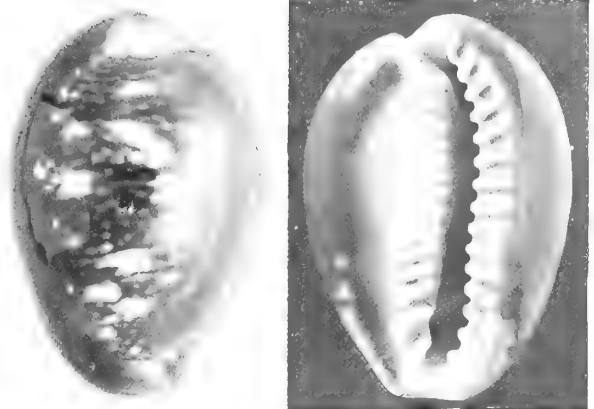


Figure 37  
*Erosaria caputserpentis kenyonae* (SCHILDER & SCHILDER, 1938)  $\times \frac{3}{4}$   
Quobba Point

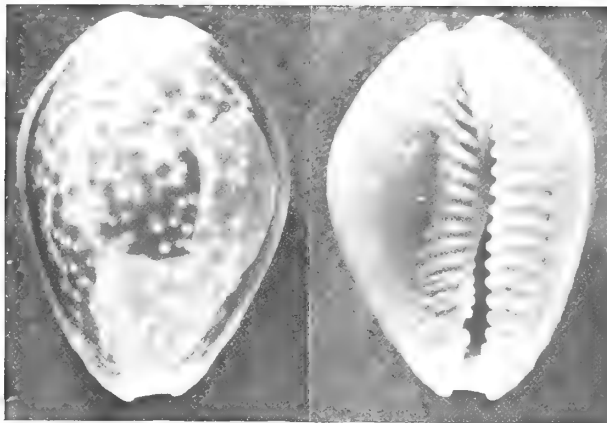


Figure 38  
*Erosaria helvola citrinicolor* IREDALE, 1935  $\times 2$   
Vlaming Head, North West Cape

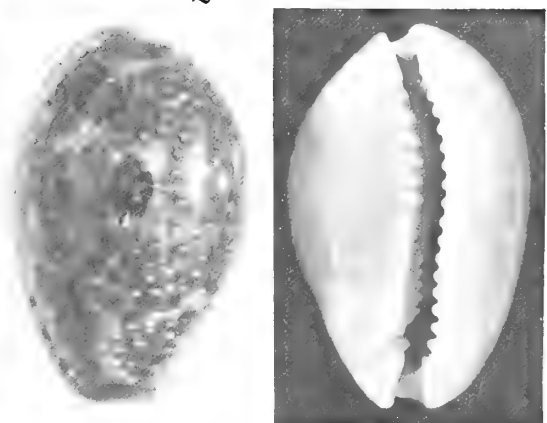


Figure 39  
*Erosaria poraria poraria* (LINNAEUS, 1758)  $\times 3$   
Vlaming Head, North West Cape

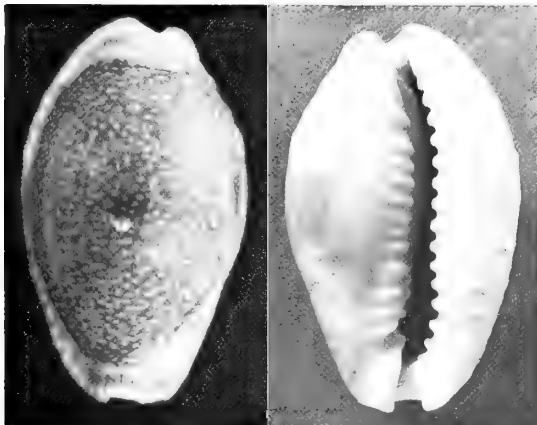


Figure 40  
*Erosaria erosa purissima* (VREDENBERG, 1919)  $\times \frac{3}{4}$   
Broome, Roebuck Bay

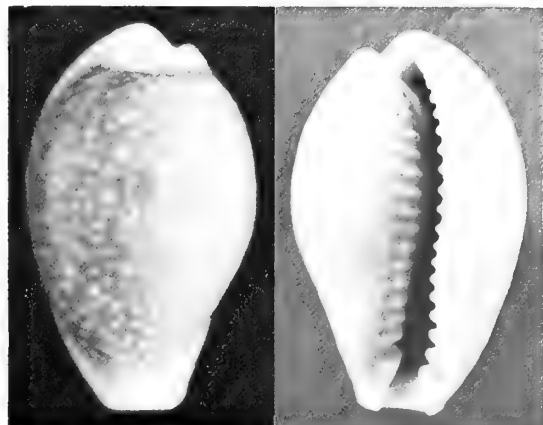


Figure 41  
*Erosaria miliaris diversa* (KENYON, 1902)  $\times 2$   
Light House Point, Broome



It should be noted that *Cypraea reevei* undergoes a very striking morphological change in shell form from Jurien Bay northward. In the Dongara area particularly, the shell loses its familiar elongately-ovate shape, becoming almost spherical (Plate 26, Figure 26). The shell is arresting in appearance, with the rear terminal flattened out and the front terminal hardly discernible; this, and its bulbously-humped appearance give it a nearly round configuration. Cate coll. no. C 3397 and no. C 3411.

17. *Cypraea (Lyncina) carneola carneola* LINNAEUS, 1758  
(Plate 26, Figure 27)

Localities: 2, 5, 8, 10, 15, 35, 36, 44, 47, 54, 57, 60, 63, 86, 89, 108, 110, 111, 114, 119, 142, 150, 153, 156, 157, 163, 176  
(29.6 18.2 15.4 25 22)

CATE (1964, p. 27, no. 60)

A specimen was found under dead coral at Alec Finlay's Island (5), Abrolhos Islands, by Terry Butterworth of Geraldton, in November 1964; Cate coll. no. C 3416.

18. *Cypraea (Lyncina) leviathan gedlingae* CATE  
subsp. nov.  
(Plate 26, Figure 28)

Localities: 64, 106, 159, 176, 177  
(64.9 38.7 32.5 33 27)

Shell large, long, heavy, massive, cylindrically-ovate, dorsally elevated; base and outer lip rounded, convex, solid, of uneven contour, bumpy; terminals large, thick, ponderous; aperture wide, straight, curving gently left adapically; teeth short, thick, distant, strong on outer lip, finer, longer, crossing columella and fossula to adaxial edge; fossula short, wide, deepening toward the front; margins thick, heavily calloused, unevenly swollen, weakly shouldered; primary dorsal color pale tomato-red, four-banded; margins, terminals and base beige, except that the upper margins and, to a lesser extent, the sides are granular appearing darker beige; beige callus over and around terminals noticeably broadened; teeth and interstices medium lavender.

The holotype (Plate 26, Figure 28) was collected at a remote place on the outer coast of the North West Cape peninsula, locally called the "Five Mile Beach" (approximately 22° 06' S Lat., 114° 01' E Long.), the distance being measured southward from the Vlaming Head Light. The statistical details of the holotype are: length 80.6 mm, width 45.3 mm, height 39.6 mm, 36 teeth on lip and 33 on the columella. The holotype will be deposited in the Type Collection of the West Australian Museum, Perth, Western Australia, where it will bear the catalogue number WAM 334-67.

Other specimens were collected between the above location and Yardie Creek (176), the most southerly locality where one additional shell was found. This new subspecies has been named for Mrs. Molly Gedling, Rott-nest Island Main Light, Western Australia. Mrs. Gedling with her husband Robert, formerly keepers of the Vlaming Head Light, collected on the beaches and reefs of both the inner and outer coasts of the North West Cape. They are largely responsible for the information we now have concerning cowries in this area.

19. *Luria (Basilitrona) isabella rumphii*  
SCHILDER & SCHILDER, 1938  
(Plate 26, Figure 29)

Localities: 44, 47, 59, 107, 119, 153, 159  
(23.1 22.9 20.5 26 20)

CATE (1964, p. 24, no. 50)

[For a discussion of this species see: CATE, 1964]

20. *Pustularia (Pustularia) cicercula cicercula*  
(LINNAEUS, 1758)  
(Plate 27, Figure 30)

Localities: 47, 153, 159, 176  
(17.6 12.4 11.2 27 23)

CATE (1964, p. 11, no. 1)

[For a discussion of this species see: CATE, 1964]

21. *Pustularia (Pustularia) globulus globulus*  
(LINNAEUS, 1758)  
(Plate 27, Figure 31)

Localities: 60, 159, 176  
(12.3 8.1 7.1 27 18)

CATE (1964, p. 12, no. 2)

[For a discussion of this species see: CATE, 1964]

22. *Monctaria (Ornamentaria) annulus annulus*  
(LINNAEUS, 1758)  
(Plate 27, Figure 32)

Localities: 10, 15, 22, 25, 36, 47, 93, 104, 108, 119, 153, 176  
(23.4 16.3 11.4 13 10)

CATE (1964, p. 15, no. 14)

[For a discussion of this species see: CATE, 1964]

23. *Monctaria (Monctaria) moneta rhomboides*  
SCHILDER & SCHILDER, 1933  
(Plate 27, Figure 33)

Localities: 4, 6, 8, 9, 10, 15, 21, 36, 37, 43, 47, 52, 58, 60, 62, 68, 72, 89, 91, 93, 94, 100, 104, 108, 110, 111, 119,

141, 146, 153, 163, 169, 171, 175, 176  
(31.5 21.8 15.9 13 12)

CATE (1964, p. 15, no. 15)

[For a discussion of this species see: CATE, 1964]

24. *Erosaria (Ravitrona) labrolineata labrolineata*  
(GASKOIN, 1849)  
(Plate 27, Figure 34)

Localities: 24, 44, 94, 119, 176  
(17.4 10.3 8.7 17 14)

CATE (1964, p. 12, no. 6)

[For a discussion of this species see: CATE, 1964]

25. *Erosaria (Ravitrona) cernica viridicolor* (CATE, 1962)  
(Plate 27, Figure 35)

Localities: 36, 53, 71, 85, 104, 118, 142, 150, 153, 156,  
159, 162, 163, 164, 165, 176  
(22.1 14.2 10.8 18 16)

CATE (1964, p. 13, no. 7)

Three specimens were found on the beach at Vlaming Head (159), North West Cape, on Easter Sunday 1964, after "Cyclone Katie" by Mrs. Molly Gedling. Cate coll. no. C 3419. Specimens were removed from a crayfish pot set in "deep" water off North Island (104), Wallabi Group, Abrolhos Islands, by W. Hemsley of Geraldton, in May, 1964. Cate coll. no. C 3413. Another specimen was collected in a crayfish pot in 12 fathoms, west of Cervantes Island (36). This shell is in the Ned Harrold collection, Victoria Park, West Australia.

26. *Erosaria (Ravitrona) helvola citrinicolor*  
IREDALE, 1935  
(Plate 28, Figure 38)

Localities: 4, 8, 15, 36, 52, 57, 62, 68, 72, 75, 89, 91, 92,  
94, 98, 105, 108, 111 112, 119, 140, 153, 159, 163, 170,  
171, 176  
(19.4 12.9 9.6 17 13)

CATE (1964, p. 13, no. 8)

[For a discussion of this species see: CATE, 1964]

27. *Erosaria (Ravitrona) caputserpentis reticulum*  
(GMELIN, 1791)  
(Plate 28, Figure 36)

Localities: 2, 6, 10, 15, 47, 93, 94, 108, 112, 119, 153, 155,  
159  
(32.7 23.7 16.6 16 12)

CATE (1964, p. 13, no. 9)

[For a discussion of this species see: CATE, 1964]

28. *Erosaria (Ravitrona) caputserpentis kenyonae*  
SCHILDER & SCHILDER, 1938  
(Plate 28, Figure 37)

Localities: 4, 8, 9, 16, 21, 35, 36, 37, 43, 52, 57, 58, 62, 68,  
72, 75, 86, 89, 90, 91, 92, 100, 104, 105, 110, 111, 140,  
141, 146, 150, 159, 163, 167, 169, 170, 171, 175, 176, 177  
(32.1 22.3 17.1 17 13)

CATE (1964, p. 13, no. 10)

[For a discussion of this species see: CATE, 1964]

29. *Erosaria (Erosaria) poraria poraria*  
(LINNAEUS, 1758)  
(Plate 28, Figure 39)

Localities: 60, 159, 176  
(16.4 10.8 8.3 19 13)

CATE (1964, p. 14, no. 11)

[For a discussion of this species see: CATE, 1964]

30. *Erosaria (Erosaria) erosa purissima*  
(VREDENBURG, 1919)  
(Plate 28, Figure 40)

Localities: 44, 104, 108, 119, 163, 176, 178  
(41.4 25.8 18.6 18 14)

CATE (1964, p. 14, no. 12)

[For a discussion of this species see: CATE, 1964]

31. *Erosaria (Erosaria) miliaris diversa* (KENYON, 1902)  
(Plate 28, Figure 41)

Localities: 33, 47, 108, 119, 153  
(37.1 24.2 19.0 21 15)

CATE (1964, p. 14, no. 13)

[For a discussion of this species see: CATE, 1964]

32. *Erosaria (Erosaria) turdus turdus* (LAMARCK, 1810)  
(Plate 29, Figure 42)

Locality: 119  
(41.0 28.9 19.7 19 15)

This specimen (Cate coll. no. C 3421) was picked up in the beach rubble on Lancelin Island (85) by Bernard E. Bardwell, Broome, in 1924. The species appears not to have been previously reported from West Australia, and this must remain a questionable species record until more definite proof of its occurrence here can be established. A second specimen of this species from West Australia is in the collection of Anthony Kalnins, Perth. His specimen (40.2 29.1 19.7 18 15) is reputed to have been collected in the same general area of Port Hedland (119). With the Erythraean *Mauritia histrio* (GMELIN, 1791) (as *M. histrio westralis* (IREDALE, 1935)) ranging into

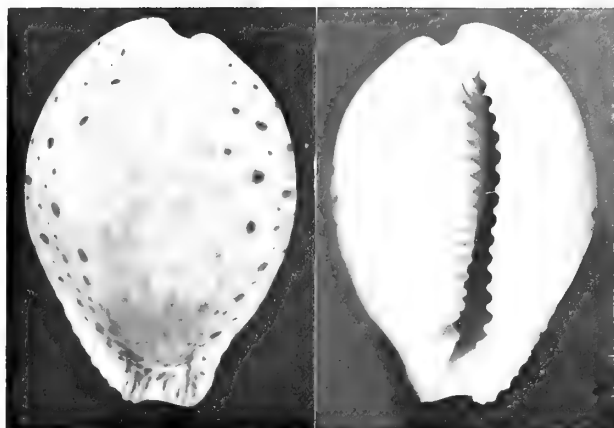


Figure 42

*Erosaria turdus turdus* (LAMARCK, 1810)  $\times \frac{3}{4}$   
Lancelin Island

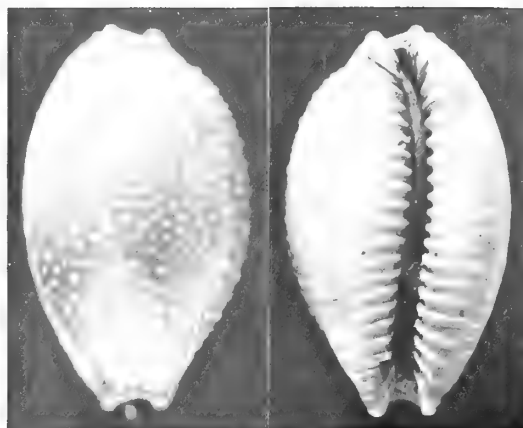


Figure 43

*Staphylaea st. staphylaea* (LINNAEUS, 1758)  $\times 3$   
Vlaming Head, North West Cape

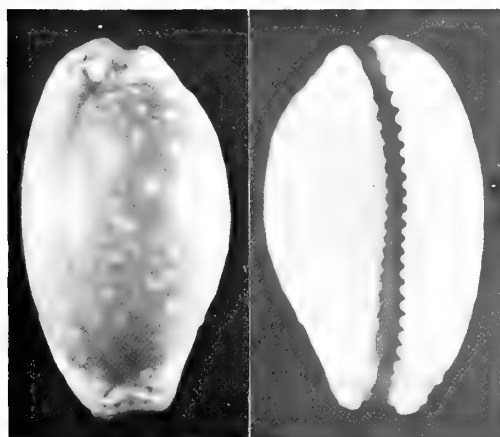


Figure 44

*Staphylaea limacina facifer* (IREDALE, 1935)  $\times 2$   
Vlaming Head, North West Cape

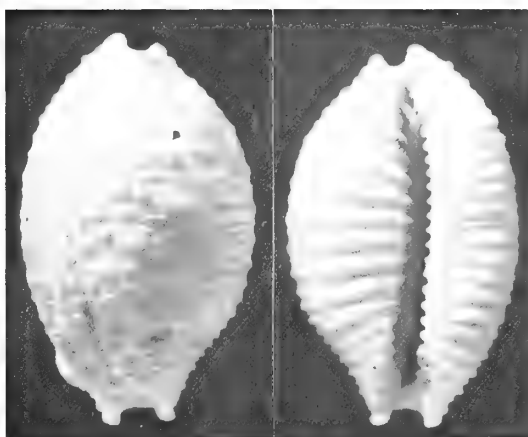


Figure 45

*Staphylaea nucleus nucleus* (LINNAEUS, 1758)  $\times 2$   
Vlaming Head, North West Cape

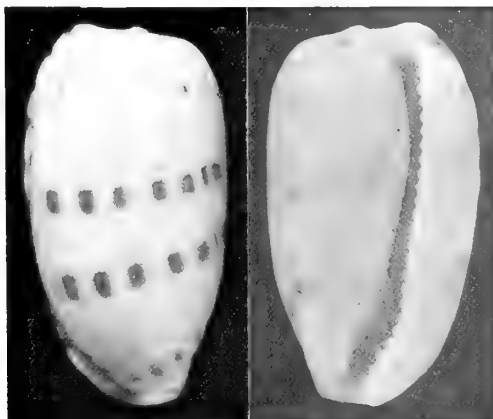


Figure 46

*Notocypraea pulicaria* (REEVE, 1846)  $\times 3$   
Busselton, Geographe Bay

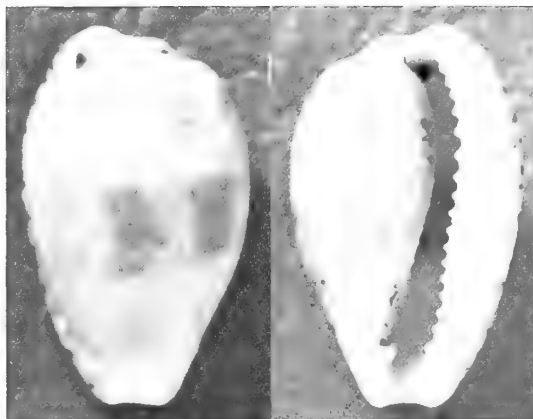


Figure 47

*Notocypraea piperita* (GRAY, 1825)  $\times 3$   
Cape Naturaliste



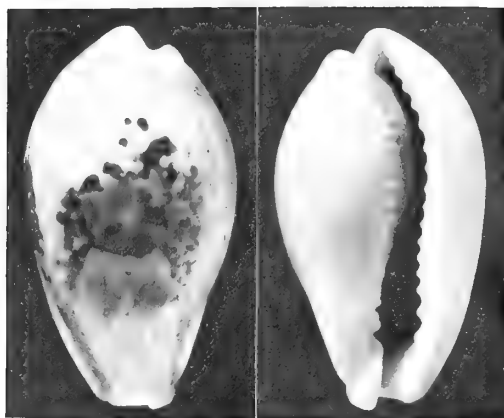


Figure 48

*Erronea subviridis dorsalis* (SCHILDER & SCHILDER, 1938) x 2  
Broome, Roebuck Bay

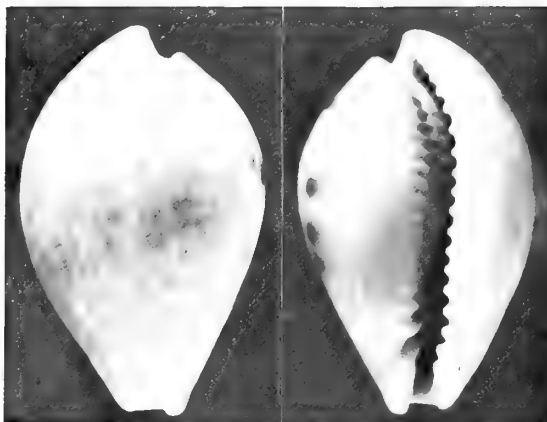


Figure 49

*Erronea pyriformis smithi* (SOWERBY, 1881) x 2  
Disaster Bay, King Sound

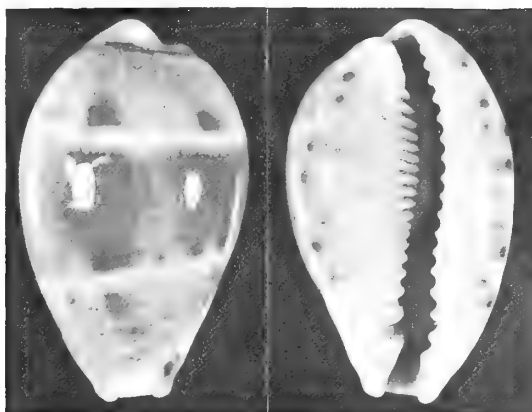


Figure 50

*Erronea walkeri continens* (IREDALE, 1935) x 2½  
Broome, Roebuck Bay

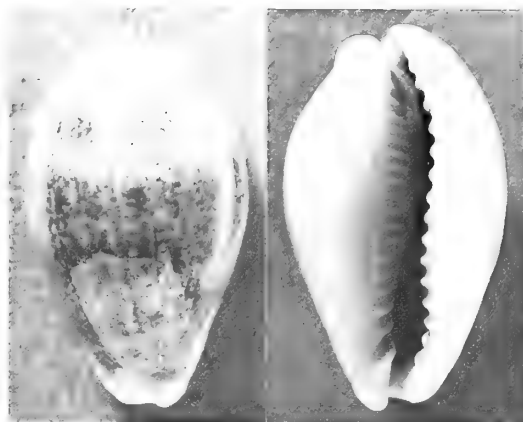


Figure 51

*Erronea ovum ovum* (GMELIN, 1791) x 1½  
Light House Point, Broome

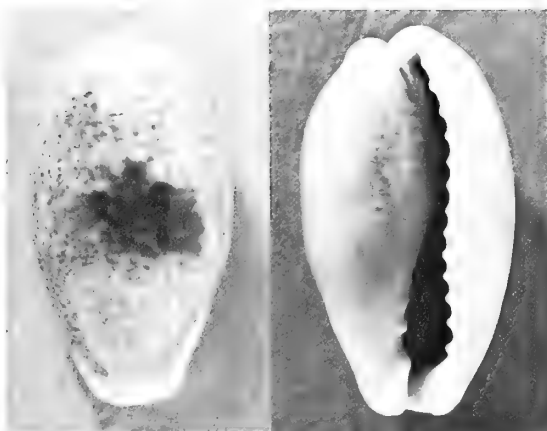


Figure 52

*Erronea erronea coxi* (BRAZIER, 1872) x 1½  
Weedong, Pender Bay



Figure 53

*Erronea cylindrica sowerbyana* SCHILDER, 1932 x 1½  
Broome, Roebuck Bay



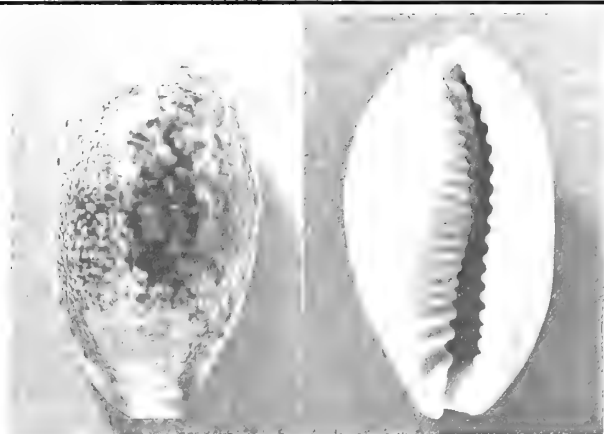


Figure 54  
*Erronea caurica blaesa* IREDALE, 1939  $\times 1\frac{1}{4}$   
Tautibiddi Well, North West Cape

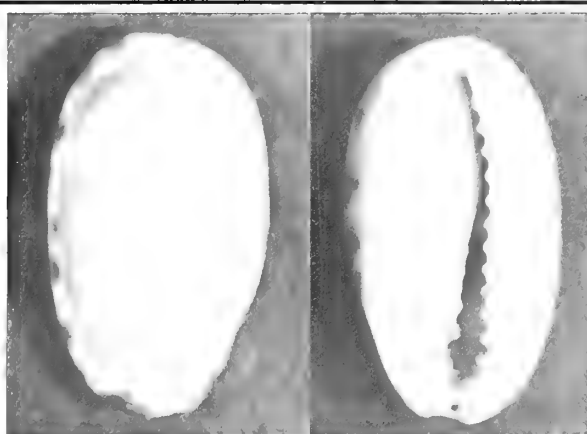


Figure 55  
*Erronea felina melvilli* (HIDALGO, 1906)  $\times 3$   
Yardie Creek, North West Cape

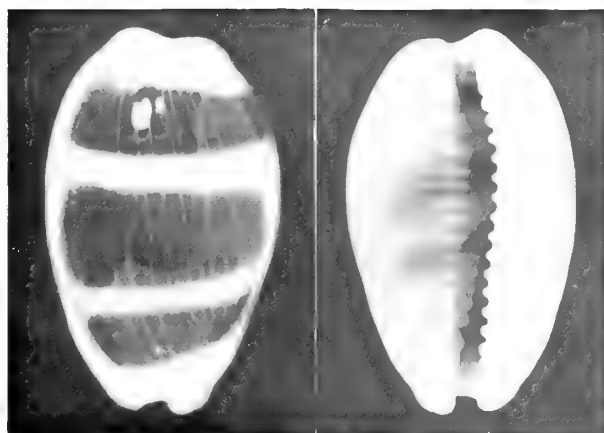


Figure 56  
*Palmadusta asellus asellus* (LINNAEUS, 1758)  $\times 3$   
Old Onslow

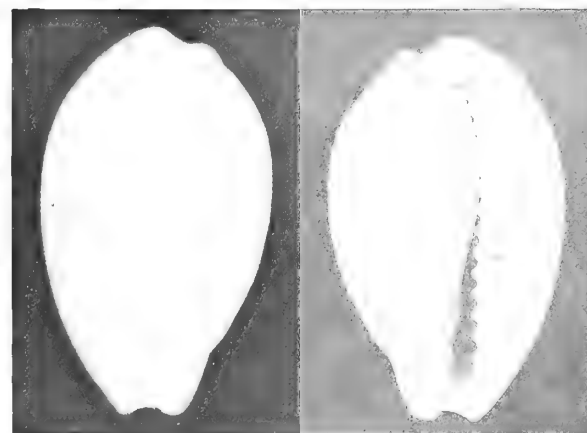


Figure 57  
*Palmadusta cl. clandestina* (LINNAEUS, 1767)  $\times 2\frac{1}{2}$   
Broome, Roebuck Bay

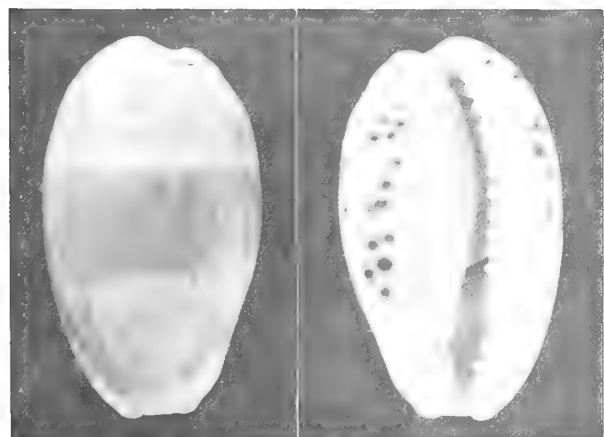


Figure 58  
*Palmadusta lutea bizonata* IREDALE, 1935  $\times 3$   
Vlaming Head, North West Cape

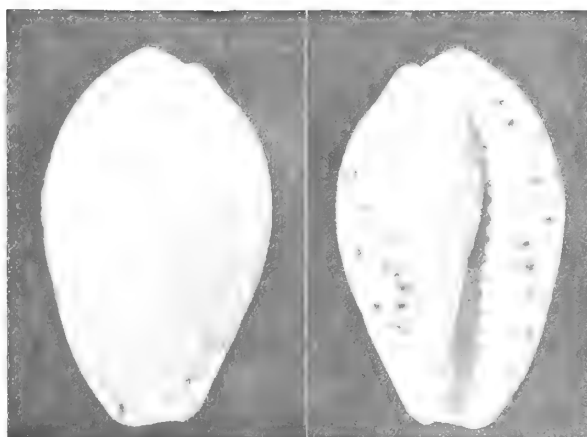


Figure 59  
*Palmadusta ziczac ziczac* (LINNAEUS, 1758)  $\times 3$   
Five Mile Beach, North West Cape



West Australian waters it seems conceivable that this species could establish itself in these waters as well.

33. *Staphylaea (Staphylaea) staphylaea staphylaea*  
(LINNAEUS, 1758)  
(Plate 29, Figure 43)

Localities: 52, 58, 159, 176  
(15.5 9.4 7.8 21 20)

CATE (1964, p. 12, no. 3)

[For a discussion of this species see: CATE, 1964]

34. *Staphylaea (Staphylaea) limacina facifer*  
(IREDALE, 1935)  
(Plate 29, Figure 44)

Localities: 34, 68, 108, 111, 159, 163, 171  
(15.9 9.2 7.5 19 16)

CATE (1964, p. 12, no. 4)

[For a discussion of this species see: CATE, 1964]

35. *Staphylaea (Nuclearia) nucleus nucleus*  
(LINNAEUS, 1758)  
(Plate 29, Figure 45)

Localities: 60, 108, 159, 176  
(24.1 12.4 11.6 22 18)

CATE (1964, p. 12, no. 5)

[For a discussion of this species see: CATE, 1964]

36. *Notocypraea (Guttacypraea) pulicaria* (REEVE, 1846)  
(Plate 29, Figure 46)

Localities: 31, 42, 88, 131, 168  
(18.6 10.6 8.2 25 24)

CATE (1964, p. 17, no. 23)

[For a discussion of this species see: CATE, 1964]

37. *Notocypraea (Notocypraea) piperita* (GRAY, 1825)  
(Plate 29, Figure 47)

Localities: 3, 26, 30, 32, 39, 67, 76  
(27.9 11.0 8.5 19 17)

Generally speaking, this is a South Australian species and is not often found in west southwest Australian waters. The South Australian Museum, Adelaide (Bernard C. Cotton Collection), however, records it living as far north on the west coast as Fremantle. I have 4 specimens collected in Bunker Bay (26),  $\frac{1}{2}$  mile east of Cape Naturaliste (Cate coll. no. C 838) from the B. E. Bardwell collection, Broome.

Many of the recognized species in the complex genus *Notocypraea* have undoubtedly arisen from a common ancestor, the most noticeably divergent forms being *N. pulicaria* and *N. piperita*. There has been much speculation

concerning the other similar species in this genus. It would appear that separating them becomes little more than a question of convenience-splitting in many cases. Especially in the *N. angustata* (GMELIN, 1791), *N. comptoni* (GRAY, 1847), *N. bicolor* (GASKOIN, 1849), etc. species complex, one usually has little difficulty in sorting out many variations to be found in a group of mixed specimens. However, *N. pulicaria* and *N. piperita* are easily separated from other members of the genus because of their readily recognizable shape and prominent color markings. These latter two species are essentially South Australian but do range into west southwest Australian waters.

38. *Erronea (Adesta) subviridis dorsalis*  
SCHILDER & SCHILDER, 1938  
(Plate 30, Figure 48)

Localities: 2, 8, 23, 33, 47, 89, 104, 108, 111, 118, 119, 153, 163, 176  
(29.1 17.5 13.9 19 16)

CATE (1964, p. 15, no. 16)

A specimen was taken from a crayfish pot set in "deep" water off North Island (104), Abrolhos Islands. O. Hewitt of Geraldton was the collector in 1963. Cate coll. no. C 3414.

39. *Erronea (Adesta) pyriformis smithi* (SOWERBY, 1881)  
(Plate 30, Figure 49)

Localities: 41, 44, 45, 81, 112, 113  
(20.8 13.8 11.8 19 16)

CATE (1964, p. 15, no. 17)

[For a discussion of this species see: CATE, 1964]

40. *Erronea (Adesta) walkeri continens* (IREDALE, 1935)  
(Plate 30, Figure 50)

Localities: 24, 121  
(23.5 13.5 11.2 21 19)

CATE (1964, p. 15, no. 18)

[For a discussion of this species see: CATE, 1964]

41. *Erronca (Erronca) ovum ovum* (GMELIN, 1791)  
(Plate 30, Figure 51)

Localities: 17, 44, 49, 60, 110  
(26.3 15.5 13.0 16 15)

CATE (1964, p. 16, no. 19)

[For a discussion of this species see: CATE, 1964]

42. *Erronea (Erronca) erronea coxi* (BRAZIER, 1872)  
(Plate 30, Figure 52)

Localities: 33, 37, 43, 80, 93, 105, 108, 114, 117, 119  
(32.0 18.1 14.8 16 15)

CATE (1964, p. 16, no. 20)

[For a discussion of this species see: CATE, 1964]

43. *Erronea (Erronea) cylindrica sowerbyana*

SCHILDER, 1932

(Plate 30, Figure 53)

Localities: 10, 47, 105, 153, 176

(28.9 14.8 12.3 18 20)

CATE (1964, p. 16, no. 21)

[For a discussion of this species see: CATE, 1964]

44. *Erronea (Erronea) caurica blaesa* IREDALE, 1939

(Plate 31, Figure 54)

Localities: 10, 14, 33, 37, 43, 47, 73, 80, 93, 108, 111, 113, 117, 119, 125, 150, 153, 155, 163, 171, 176, 178

(41.3 23.1 18.5 18 16)

CATE (1964, p. 16, no. 22)

Specimens were found at Inner (West) Beach (171), one mile north of Wreck Point, which is located at the west end of Pelsart Island, Abrolhos Islands. Collector: James Seabrook, Fisheries vessel *Lancelin*, March 1965. Cate coll. no. C 3415.

45. *Erronea (Melicerona) felina melvilli* (HIDALGO, 1906)

(Plate 31, Figure 55)

Locality: 176

Shell data: Length 16.7, width 9.8, height 7.3 mm; number of teeth on lip - 13, on columella - 13.

As far as we have been able to ascertain, this species is very rare in West Australia. A single dead specimen was found wedged in the bottom of a tide pool at Yardie Creek (176), approximately 7 miles south of Vlaming Head Light House, North West Cape - the only specimen of *Erronea felina melvilli* known to me from West Australia. Even though the shell was dead-collected, it would seem probable that the species lives in this area. The locality is so remote, so sparsely settled that the possibility of its having been artificially introduced seems unlikely. However, until living specimens are collected in the area I am listing it only tentatively in the West Australian fauna.

46. *Palmadusta (Palmadusta) asellus asellus*

(LINNAEUS, 1758)

(Plate 31, Figure 56)

Localities: 24, 60, 108, 119, 159, 160

(17.6 10.8 8.5 17 14)

CATE (1964, p. 17, no. 24)

[For a discussion of this species see: CATE, 1964]

47. *Palmadusta (Palmadusta) clandestina clandestina*

(LINNAEUS, 1767)

(Plate 31, Figure 57)

Localities: 8, 15, 33, 37, 43, 47, 98, 108, 111, 117, 119, 142, 153, 162, 163, 176

(18.9 11.6 9.4 19 15)

CATE (1964, p. 17, no. 25)

[For a discussion of this species see: CATE, 1964]

48. *Palmadusta (Palmadusta) saulae crakei* CATE,

subspec. nov.

(Plate 34, Figures 73a, 73b, 73c)

Localities: 117a, 119, 124

(26.0 15.2 11.7 22 17)

CATE (1964, p. 17, no. 26)

Shell large, broad, narrowing quickly abapically, bulbously ovate, umbilicate; teeth short, well defined on outer lip, intermittently so on columella, but extending across fossula; front and rear terminals noticeably rostrate; right margin thick, left side uncalledous, curving smoothly from dorsum to base; primary shell color pearl-grey, with large central brown dorsal blotch that covers at least 20% of upper surface, the rest of dorsum thickly sprinkled with minute brown spots; margins copiously flecked with larger brown spots, with a brown spire blotch; base mostly devoid of spotting, of a lighter basic grey color, as are teeth; terminal openings, columella, fossula, and interstices bright orange-yellow; foot and mantle brilliant orange, marked with fawn-colored spots.

*Palmadusta saulae crakei* differs from *P. saulae nugata* in having a larger, broader, heavier shell; by the orange interstices (*P. s. nugata* normally does not have color in the interstices); by larger and heavier teeth; and by larger and more prominent chestnut spotting at the margins. It differs from *P. saulae siasiensis* CATE, 1960 (Plate 34, Figure 75) by a larger, wider, heavier shell; by a wider, more curving aperture; by heavier, more well-defined teeth; and by the larger, more numerous dorsal spots.

This new molluscan form is restricted, as presently known, to the area from Port Hedland (119) north to Port Darwin (117a). The specimen illustrated here was collected at Quondong, a popular fishing area 35 miles north of Broome, which is here designated the type locality (17° 59' S Lat., 122° 14' E Long.). Its range is distinctly separated geographically from its nearest allopatric relative, *Palmadusta saulae nugata* IREDALE, 1935, from the Queensland coast, eastern Australia.

This new subspecies is presently known from 3 specimens: one from Port Darwin, the Port Hedland shell, and the specimen discussed in this paper. There is also an un-

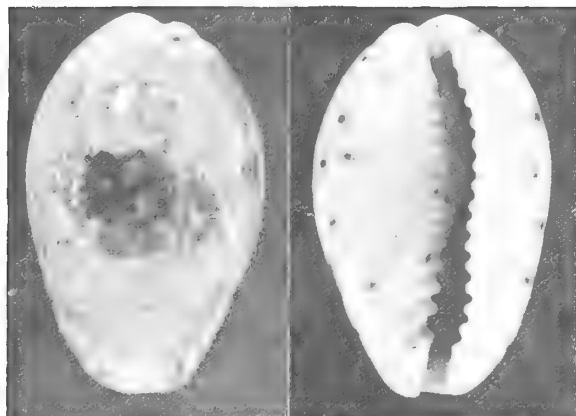


Figure 60  
*Palmadusta gracilis hilda* (IREDALE, 1939)  $\times 3$   
Cape Preston, Onslow

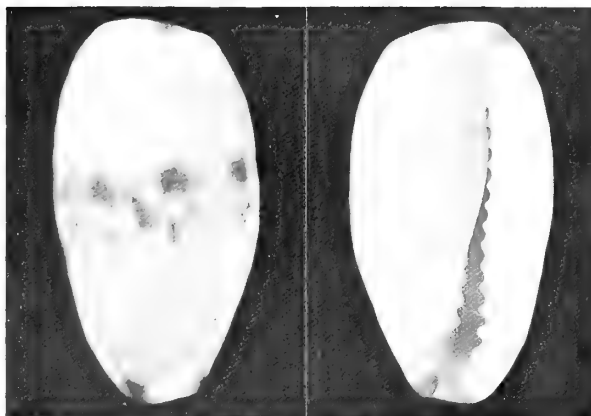


Figure 61  
*Palmadusta fimbriata fimbriata* (GMELIN, 1791)  $\times 4$   
Vlaming Head, North West Cape



Figure 62  
*Palmadusta hammondae dampierensis* SCHILDER &  
CERNOHORSKY, 1965  $\times 4$   
Port Hedland

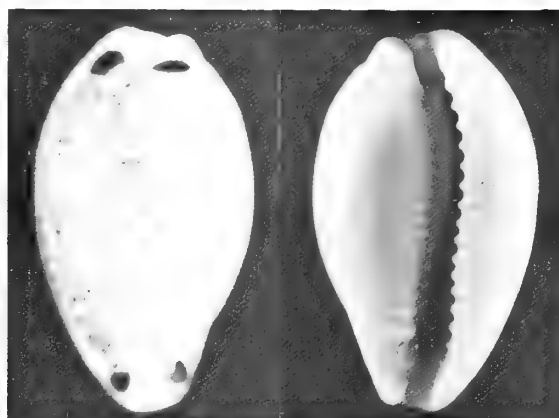


Figure 63  
*Bistolida quadrimaculata thielei* (SCHILDER &  
SCHILDER, 1938)  $\times 2\frac{1}{4}$   
Sunday Island, King Sound

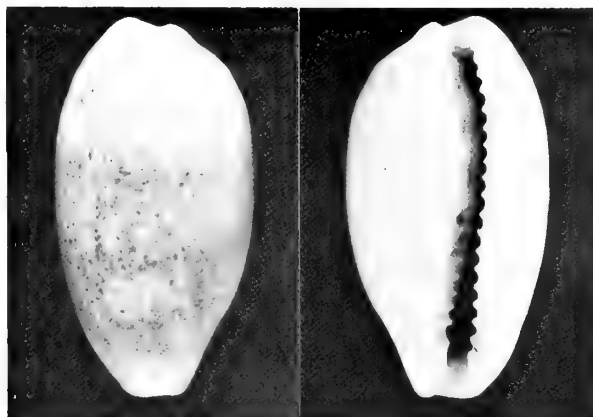


Figure 64  
*Bistolida pallidula simulans* SCHILDER & SCHILDER,  
1940  $\times 2\frac{1}{4}$   
Broome, Roebuck Bay

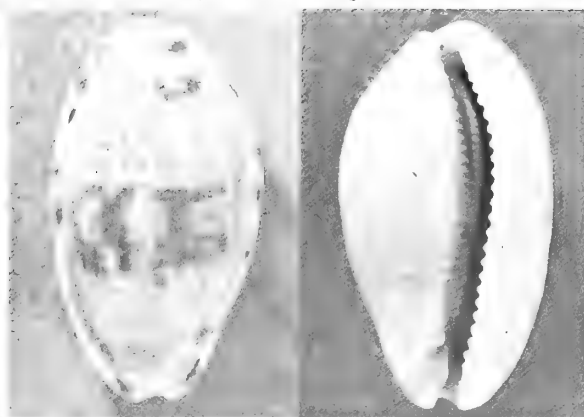


Figure 65  
*Bistolida teres teres* (GMELIN, 1791)  $\times 1\frac{1}{2}$   
Broome, Roebuck Bay



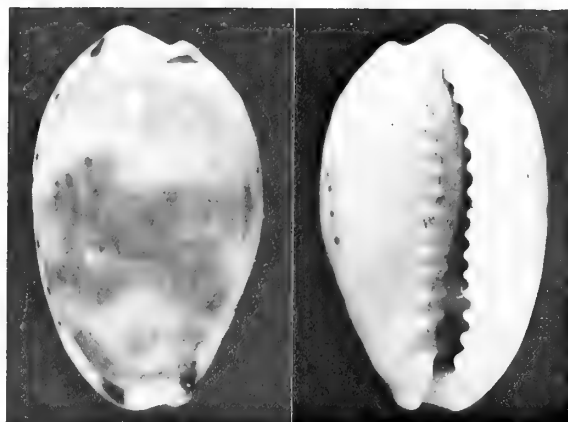


Figure 66  
*Bistolida kieneri kieneri* (HIDALGO, 1906)  $\times 4$   
Broome, Roebuck Bay

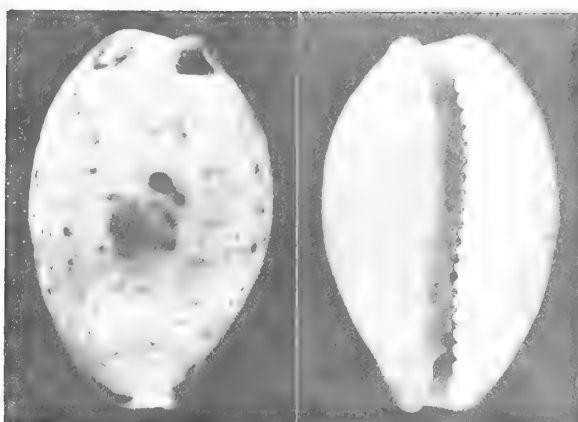


Figure 67  
*Bistolida hirundo cameroni* IREDALE, 1939  $\times 3$   
Broome, Roebuck Bay

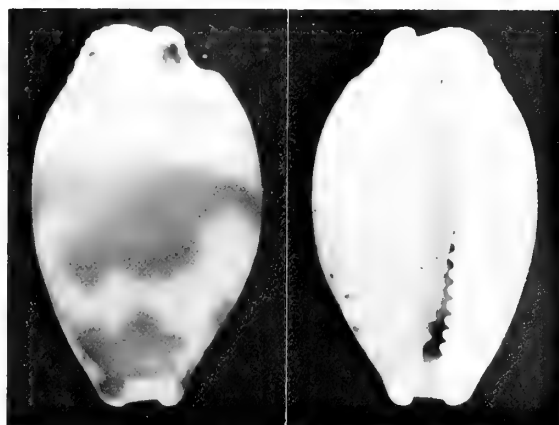


Figure 68  
*Bistolida ursellus ursellus* (GMELIN, 1791)  $\times 4$   
Broome, Roebuck Bay

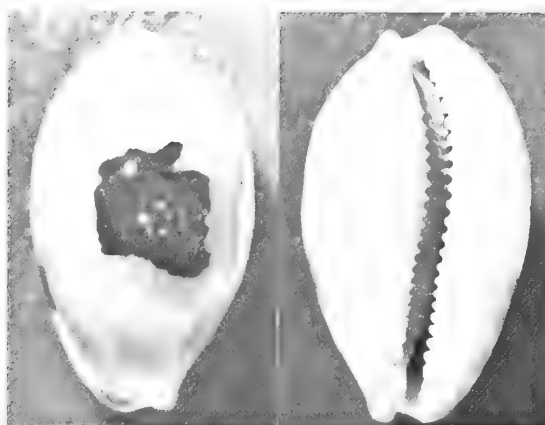


Figure 69  
*Bistolida stolidus stolidus* (LINNAEUS, 1758)  $\times 2$   
Five Mile Beach, North West Cape

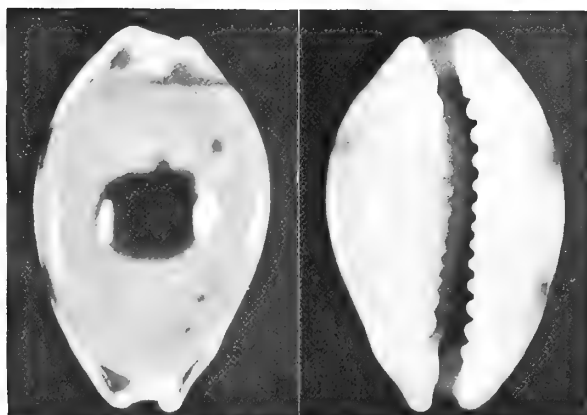


Figure 70  
*Bistolida brevidentata* (SOWERBY, 1870)  $\times 2\frac{1}{2}$   
Cable Beach, Broome

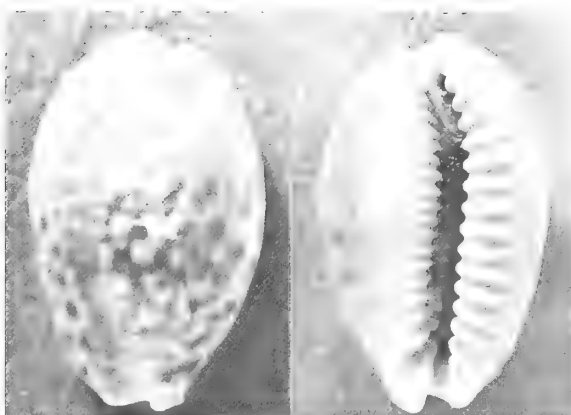


Figure 71  
*Cribrarula chinensis whitworthi* (CATE, 1964)  $\times 1\frac{1}{2}$   
Vlaming Head, North West Cape



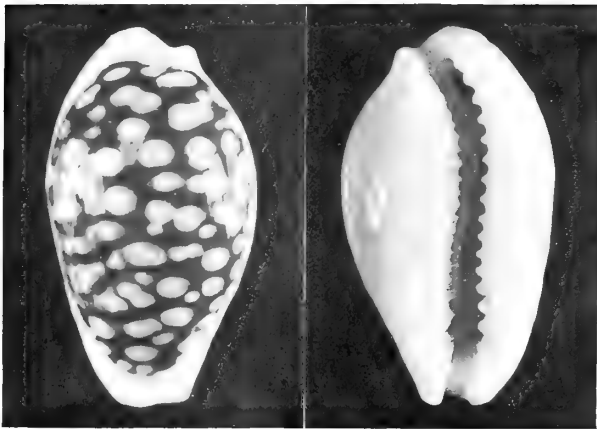


Figure 72  
*Cribrarula cribraria fallax* (E. A. SMITH, 1881)  $\times 2$   
Broome, Roebuck Bay



Figure 73 a  
*Palmadusta saulae crakei* subsp. nov.  $\times 1\frac{3}{4}$   
Broome, Roebuck Bay

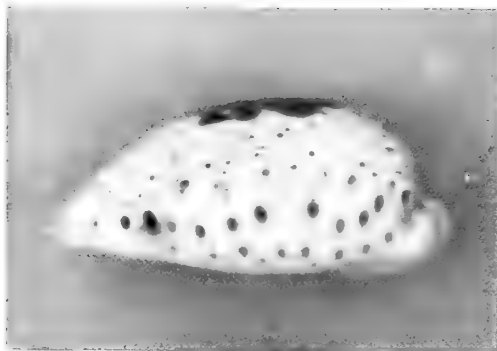


Figure 73 b  
*Palmadusta saulae crakei* subsp. nov.  $\times 1\frac{3}{4}$   
Left Lateral Aspect

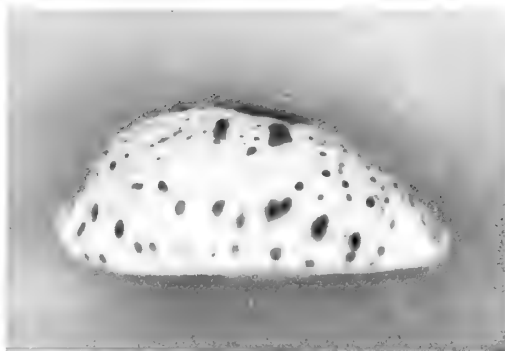


Figure 73 c  
*Palmadusta saulae crakei* subsp. nov.  $\times 1\frac{3}{4}$   
Right Lateral Aspect

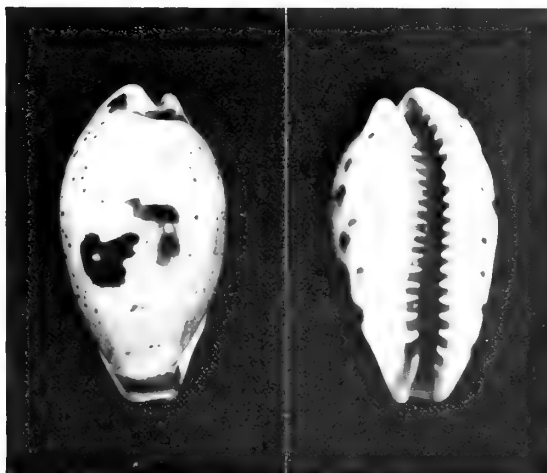


Figure 74  
*Palmadusta saulae saulae* (GASKOIN, 1843)  $\times 1\frac{1}{2}$   
Manila Bay, Philippines

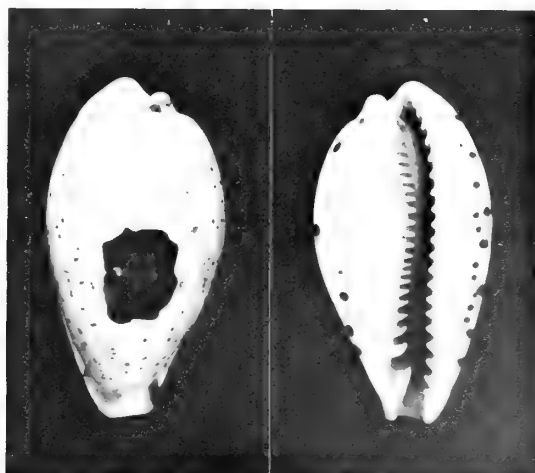


Figure 75  
*Palmadusta saulae siasiensis* (CATE, 1960)  $\times 1\frac{1}{2}$   
Siasi Island, Sulu Sea



verified shell in a Broome collection. A detailed description will be found in CATE (1964), with other pertinent information.

For comparative purposes I have added illustrations of *Palmadusta saulae saulae* (GASKOIN, 1843) (Plate 34, Figure 74) and *P. saulae siasiensis* (Plate 34, Figure 75) to more clearly illustrate the differences to be found in these shells. *Palmadusta saulae crakei* differs from the typical Philippine *P. s. saulae* by being a larger, broader, heavier shell; by having more abundant and larger chestnut-brown spots on the dorsum as well as a larger dorsal color blotch; by having the terminals less protruding, more massive, and without color on the terminal collars; by the absence of the large brown spots usually found on the margins; by the paler orange in the interstices; and by the aperture, which curves more at either end of the shell.

The holotype will be deposited at the West Australian Museum, Perth, where it will bear the catalogue number WAM 1321-67. This subspecies is named in honor of Theodore Crake, who probably found the first animal of this taxon living in Western Australian waters. Mr. Crake has also assisted to a great degree in the study of the cowries occurring in the Broome area and its environs.

49. *Palmadusta (Palmadusta) lutea bizonata*

IREDALE, 1935

(Plate 31, Figure 58)

Localities: 33, 47, 108, 119, 176

(16.5 9.9 8.3 18 17)

CATE (1964, p. 18, no. 27)

[For a discussion of this species see: CATE, 1964]

50. *Palmadusta (Palmadusta) ziczac ziczac*

(LINNAEUS, 1758)

(Plate 31, Figure 59)

Localities: 119, 157, 159, 176

(16.4 9.7 7.7 18 18)

CATE (1964, p. 18, no. 28)

[For a discussion of this species see: CATE, 1964]

51. *Palmadusta (Purpuradusta) gracilis hilda*

(IREDALE, 1939)

(Plate 32, Figure 60)

Localities: 15, 33, 35, 37, 43, 68, 93, 98, 103, 108, 117, 119, 153, 159, 176

(15.2 10.1 7.9 15 14)

CATE (1964, p. 18, no. 29)

[For a discussion of this species see: CATE, 1964]

52. *Palmadusta (Purpuradusta) fimbriata fimbriata*

(GMELIN, 1791)

(Plate 32, Figure 61)

Localities: 58, 119, 121, 159

(11.1 6.5 5.1 15 16)

CATE (1964, p. 18, no. 30)

[For a discussion of this species see: CATE, 1964]

53. *Palmadusta (Purpuradusta) hammondae dampierensis*

SCHILDER & CERNOHORSKY, 1965

(Plate 32, Figure 62)

Localities: 46, 57, 119, 126, 166, 176

(15.3 8.6 7.1 16 16)

CATE (1964, p. 18, no. 31)

[For a discussion of this species see: CATE, 1964]

54. *Bistolida (Blasicrura) quadrimaculata thielei*

SCHILDER & SCHILDER, 1938

(Plate 32, Figure 63)

Localities: 82, 121

(20.9 11.8 10.1 17 16)

CATE (1964, p. 19, no. 32)

[For a discussion of this species see: CATE, 1964]

55. *Bistolida (Blasicrura) pallidula simulans*

SCHILDER & SCHILDER, 1940

(Plate 32, Figure 64)

Localities: 108, 116, 119

(18.6 10.2 8.1 21 17)

CATE (1964, p. 19, no. 33)

[For a discussion of this species see: CATE, 1964]

56. *Bistolida (Blasicrura) teres teres* (GMELIN, 1791)

(Plate 32, Figure 65)

Localities: 8, 24, 59, 89, 98, 108, 111, 142, 150, 159, 163, 176

(27.3 15.6 12.5 24 25)

CATE (1964, p. 20, no. 38)

[For a discussion of this species see: CATE, 1964]

57. *Bistolida (Derstolida) kieneri kieneri* (HIDALGO, 1906)

(Plate 33, Figure 66)

Localities: 24, 176

This species is rare in West Australia, with only 3 specimens collected so far, to my knowledge. For this

Largest shell (176):	16.7	9.8	7.3	15	13
Medium shell (24):	14.3	8.5	6.5	16	11
Smallest shell (24):	14.2	8.3	6.6	15	14

reason statistical data of all three shells are given here. The larger shell (176) was collected by Mrs. Molly Gedling of Vlaming Head Light, North West Cape, at Yardie Creek in September 1964. One of the other 2

shells was collected at Gantheaume Point, Broome (24), in 1956 by Archer Whitworth, Broome; and the last shell was collected by Theodore Crake, Broome, at Entrance Point, Broome, in 1964. This latter animal was found living among *Bistolida hirundo cameroni* (IREDALE, 1939).

58. *Bistolida (Derstolida) hirundo cameroni*  
(IREDALE, 1939)  
(Plate 33, Figure 67)

Localities: 15, 47, 108, 119, 153, 176  
(16.4 10.8 8.4 19 15)

CATE (1964, p. 19, no. 34)

[For a discussion of this species see: CATE, 1964]

59. *Bistolida (Derstolida) ursellus ursellus* (GMELIN, 1791)  
(Plate 33, Figure 68)

Locality: 24  
(11.1 6.9 5.5 18 17)

CATE (1964, p. 19, no. 35)

[For a discussion of this species see: CATE, 1964]

60. *Bistolida (Bistolida) stolidata stolidata* (LINNAEUS, 1758)  
(Plate 33, Figure 69)

Localities: 46, 60, 119, 159  
(27.7 15.8 12.9 23 18)

CATE (1964, p. 20, no. 36)

[For a discussion of this species see: CATE, 1964]

61. *Bistolida (Bistolida) brevidentata* (SOWERBY, 1870)  
(Plate 33, Figure 70)

Localities: 24, 119, 176  
(22.6 13.6 10.9 15 13)

CATE (1964, p. 20, no. 37)

This species is clearly separable from *Bistolida s. stolidata* because of the total absence of the lateral marks at each quarter of the shell. In its dorsal aspect the central color blotch is usually more conservative and rounder in appearance; the teeth are shorter and more rounded as well. This taxon is here given full specific status since it occupies the same habitat in West Australia as *B. s. stolidata*, and therefore should not be regarded as subspecific to it.

62. *Cribrarula<sup>1</sup> (Ovatipsa) chinensis whitworthi*  
(CATE, 1964)  
(Plate 33, Figure 71)

Localities: 36, 53, 89, 163, 176  
(32.5 19.6 16.1 16 14)

CATE (1964, p. 20, no. 39)

A specimen was taken from a crayfish pot set on a coral bottom in 65 fathoms, 10 miles west northwest of West Wallabi Island, Abrolhos Islands by Martin van der Oord of Geraldton in June 1964. Cate coll. no. C 2907.

63. *Cribrarula (Cribrarula) cribraria fallax*  
(E. A. SMITH, 1881)  
(Plate 34, Figure 72)

Localities: 36, 52, 66, 68, 91, 111, 118, 119, 144, 159, 163, 176, 180

(26.1 16.1 12.8 18 17)

CATE (1964, p. 21, no. 40)

A specimen was removed from a crayfish pot set at 23 fathoms  $\frac{1}{2}$  mile east of the first island south of Little North Island (91), Abrolhos Islands by Alec Gilbertson of Geraldton, in June 1964. Cate coll. no. C 2943.

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<sup>1</sup> see SCHILDER & SCHILDER, 1967

# A Checklist of Intertidal Mollusks for Bahía Willard and the Southwestern Portion of Bahía San Luis Gonzaga State of Baja California, Mexico

BY

HELEN DUSHANE<sup>1</sup>

AND

GALE G. SPHON<sup>2</sup>

Conchological Club of Southern California, Los Angeles, California 90007

(Plate 35; 1 Map)

## INTRODUCTION

THE BAYS OF WILLARD AND SAN LUIS GONZAGA are located in the State of Baja California, Mexico, on the Gulf of California (Lat. 29° 48' N, Long. 114° 24' W), 200 km south of the International Boundary. In time, with improved road conditions, it is probable that this area will become a favorite locality for collectors. For this reason we consider it desirable to present a checklist of the intertidal mollusks that have been found there.

This list is not intended to be all inclusive, but presents a preliminary survey indicating the species obtained in a partially explored area. It is based on the results of a joint field trip made by the authors from February 1 to 6, 1966 during which 310 species were collected. Mrs. Faye B. Howard collected mollusks at both Willard and Gonzaga Bays during the month of May of 1957, 1958, 1959, and 1960. Her collection was made available to us. Dr. Homer King and the junior author collected specimens in January 1960; a report of the specimens they obtained is included here. Dr. James H. McLean collected on February 2, 1966 at Gonzaga Bay. His list of mollusks collected is included in this paper.

The nudibranch fauna of the entire Panamic province is very poorly known. Accordingly, a determined effort was made to collect these animals and to transport them alive to La Jolla, California, where they were given to James R. Lance for photographing and identifying (LANCE, 1966).

The fauna of the Bays of Gonzaga and Willard has not been as intensively collected as that of some of the other areas in the Gulf of California, such as Punta Peñasco (LOWE, 1935), Guaymas (DUSHANE & POORMAN, 1967), Puertecitos (DUSHANE, 1962), Bahía de los Angeles (MCLEAN, 1961) and Isla Espíritu Santo (KEEN, 1964).

## PREVIOUS COLLECTING IN THE BAYS OF WILLARD AND GONZAGA

Historically, the first collectors in this area were the aborigines who are reported to have worn "pearls, berries, white round shells from small snails, and pieces of shell and mother of pearl" (DUNNE, 1952). The earliest historian, Clavigero, 1788 (1937 transl.), reporting on physical conditions in Baja California prior to the expulsion of the Jesuits in 1768, tells "Of the testaceous there are mussels, murex shellfish, mother-of-pearl, and many other kinds of periwinkles, mollusks and oysters."

COAN (1965) reports on the shells of an Indian kitchen midden with a table of mollusks from the midden. He

<sup>1</sup> 15012 El Soneto Drive, Whittier, California 90605

<sup>2</sup> Malacologist, Santa Barbara Museum of Natural History, Santa Barbara, California 93105

shows a photograph of shell designs superimposed on the sand dunes. However, one should be most careful in reporting shell figures supposedly made by Indians. Usually the aborigines were too busy obtaining their daily food to spend time making figures in the sand. The Jesuit priests who were the first Caucasians to live in these regions made no report of such designs (ENGELHARDT, 1929).

Three records of molluscan collecting in the vicinity of Willard and San Luis Gonzaga Bays appear in the literature: (1) The 1921 expedition of the California Academy of Sciences to the Gulf of California anchored in San Luis Gonzaga Bay, dredged there and at San Luis Island to the west. A general account of this expedition was given by SLEVIN (1923). Mollusks taken during this investigation have been partially recorded by BAKER, HANNA & STRONG (1928): Pyramidellidae; BAKER (1926): Triphoridae; BAKER & HANNA (1927): Opisthobranchiata; BAKER, HANNA & STRONG (1938): Cerithiopsidae, Cerithiidae and Cyclostrematidae. (2) The Allan Hancock Pacific Expeditions of 1937 and 1940 collected off Willard Point, at Willard Island, and in Gonzaga Bay. FRASER (1943) listed 8 dredging stations and one shore station, but the mollusks remain largely unworked. However, 21 specimens of *Dentalium hancocki* EMERSON were reported by EMERSON (1956) from one dredge haul in Gonzaga Bay. (3) The 1957 expedition of the Puritan-American Museum of Natural History reported 2 dredging stations, one diving and one shore station within Gonzaga Bay. A general account of this expedition was given by EMERSON (1958).

Shore collected specimens are the main concern of this report, but several dredging records are worthy of mention. *Cantharus bilirata* (REEVE) (fragments only), *Cancellaria obesa* SOWERBY, *Clavus melea* (DALL), *Daphnella allemani* (BARTSCH), *D. crebriforma* (SHASKY & CAMPBELL) and *Trigonostoma campbelli* SHASKY were dredged in 50 m off Punta Final, January 1, 1961 by Shasky, Campbell and Sphon (SHASKY, 1961). On the south side of Willard Island in Gonzaga Bay, in 50 m, *Anatina cyprinus* (WOOD) was taken by the same trio (CAMPBELL, 1961). CAMPBELL (1964) reports 3 specimens of *Terebra adairensis* CAMPBELL from Gonzaga Bay. DONOHUE (1966) reports 2 specimens of *Trivia myrae* CAMPBELL dredged off Punta Final. The senior author of this paper dredged specimens of *Acmaea semirubida* DALL, *Diodora pusilla* BERRY, *Coralliophila incompta* BERRY, *Pleuroliria picta* (REEVE), *Aspella bakeri* HERTLEIN & STRONG, *Clavus aeginus* DALL, *Triphora hannai* BAKER, *T. oweni* BAKER, and *Metaxia convexa* (CARPENTER) off San Luis Island in October 1966 and December 1966 in 11 m.

## OCEANOGRAPHIC CONSIDERATIONS

Very little is known concerning meteorological and oceanographic conditions at Gonzaga and Willard Bays. No year around water temperature data are available (RODEN & GROVES, 1959: p. 11), but local inhabitants claim the air temperature rarely goes above 100° in the hot months of July and August (personal communication Alfonsina Urquidez V.). The lowest temperatures are about 40°F. Temperature ranges were corroborated by José Samano Sanchez, Servicio Federal, Forestal y de la Fauna, who is the conservation inspector for this area. Pacific storms create violent winds at Gonzaga Bay, less so at the adjacent Willard Bay. Gonzaga Bay is separated from Willard Bay to the west by a sand spit extending at low tide to Willard Island. This small island, together with the mountains to the west, serve to protect Willard Bay from the wind. Gonzaga Bay is an open indentation in a low lying valley, exposed to winds. The floor of Gonzaga Bay is sandy with many subtidal sand bars, while that of Willard Bay is silty and muddy, with a vast expanse of mud flat at low tide. At high tide a depth of 14 feet (ca. 4 m) of water joins Willard and Gonzaga Bays. The tidal range is about 4 to 5 m. The sea floor outside the bays slopes gradually to a depth of 400 fathoms (approximately 729 m). A small archipelago of 6 islands stretches westward from Gonzaga Bay, the largest and most southerly of which is Isla San Luis, 5 miles offshore. Around these islands, known as Las Islas Encantadas, there are swift currents. The current on the west side of the chain runs counter to that on the east side. Yet the main current of the Gulf of California on the west shore runs south (BERRY, 1954: p. 24; RODEN, 1958: pp. 24 and 33). These factors create a maelstrom which probably is influential in mixing the waters within Gonzaga and Willard Bays. Since extensive evaporation, which increases salinity, occurs in the shallow protected bays of Bahía Concepcion, Bahía San Felipe, and Bahía Adair (RODEN & GROVES, 1959: p. 16) one would expect the same to be true at Bahías Willard and Gonzaga.

## FAUNAL RELATIONSHIPS

This checklist records 310 species of mollusks, of which 102 are pelecypods, 196 are gastropods, and 12 are chitons. Of this number 7 are doubtfully identified ("cf.") and 6 are identified only to genus. This report extends the known range northward for specimens of 32 species (range data from KEEN, 1958, and McLEAN, 1961). These are *Barbatia lurida*, *B. gradata*, *Anadara cepoides*, *Noetia reversa*, *Glycymeris tessellata*, *Mytella speciosa*, *Lithophaga attenuata*, *Gregariella denticulata*, *Diplodon-*

*ta caelata*, *Lasaea subviridis*, *Chama frondosa mexicana*, *Pseudochama panamensis*, *Pitar consanguineus*, *Apolymetis cognata*, *Cyathodonta lucasana*, *C. undulata*, *Petalochonchus complicatus*, *P. flavescens*, *Sinum noyesii*, *Decipifus gracilis*, *Anachis taeniata*, *Nassarina pammicra*, *Engina reevei*, *Clathrodrillia maura*, *Crassispira aterrima*, *C. monilifera*, *Mangelia finitima*, *M. subdiaphana*, *Tenaturris carissima*, *Terebra albocincta*, *Acteocina carinata*, *Pyramidella panamensis*. The northernmost locality for each of these is mentioned in the checklist. One species, *Lamellaria sharonae* WILLETT, 1939 (type locality: Anaheim Bay, Orange County, California) was taken on the south side of Willard Island. Two southward extensions of range in the Gulf of California are specimens of *Terebra berryi*, reported by DUSHANE (1962) from Puertecitos, and *Melampus mouseleyi* (type locality, Bahía de Adair, Sonora, Mexico).

Although the molluscan fauna is predominantly Panamic, some members of the Californian province are represented in the northern Gulf. PARKER (1963: p. 124) presents a hypothesis attempting to explain the presence of California province mollusks in the Gulf of California. He considers it possible that the cold water fauna of California entered the Gulf of California area during the colder parts of the Pleistocene and during a time when the sea level in the Gulf was at least 100 m lower than at present. The lowered sea level left a narrow continental shelf along which mollusks might migrate northward into the Gulf. Specimens of the following species occurring in both the Californian and Panamic provinces are also to be found at Gonzaga and Willard Bays: *Chione californiensis*, *Transennella tantilla*, *Sphenia fragilis*, *Polinices reclusianus*, *Lamellaria sharonae*, *Hermisenda crassicornis*, *Spurilla chromosoma*, and *Rostanga pulchra*.

The faunal element restricted to the northern and northwestern shores of the Gulf is less well known but includes: *Acmaea strongiana*, *Nomaeopelta dalliana*, *Cantharus macrospira*, *Turritella anactor*, *Terebra berryi*, *T. dushanae*, *Recluzia palmeri*, and *Acanthochitona exquisita*. There are also some peculiarities in faunal distribution on the western side of the Gulf of California. *Anachis varia* and *Parametaria dupontii* are to be found from San Felipe south to Gonzaga Bay, but are not reported by McLEAN (1961) from Los Angeles Bay. Specimens of *Nassarina pammicra* reported by McLEAN (op. cit.) from Los Angeles Bay as a range extension northward from Nicaragua have also been collected by DUSHANE (1964) at Puertecitos as well as at Gonzaga Bay. There are a few species which occur in a very limited area such as *Terebra berryi* and *T. dushanae* (type locality for both: Puertecitos). The former occurs living at Gonzaga Bay but has not been found at San Felipe to the north or at Los Angeles Bay to the south. The latter species occurs uncommonly at Agua de Chale, 24

miles north of Puertecitos; one beach specimen has been taken at Gonzaga Bay; it is unrecorded at Los Angeles Bay. *Strombina dorsata* occurs at both Gonzaga Bay and at Puertecitos but is unrecorded from Los Angeles Bay. *Mitra erythrogramma*, usually taken by dredging, is fairly common intertidally at Willard Bay.

A considerable number of species common to the eastern shore of the Gulf of California is apparently absent from Gonzaga and Willard Bays. These include the following species, which we have collected at either Guaymas or Punta Peñasco, or both: *Astraea unguis*, *Turritella gonostoma*, *Mitra lens*, *Agaronia testacea*, *Cypraea arabicula*, *Thais kiosquiformis*, *Thais speciosa*, *Purpura patula pansa*, *Conus brunneus*, *C. purpurascens* and *C. virgatus*. These are essentially the same species McLEAN (1961) also reported to be absent from Los Angeles Bay.

SYSTEMATIC ACCOUNT

The following format is adopted:

- 1. The order in the checklist, the nomenclature, and the species number is that given by KEEN (1958). References to species listed by KEEN may be located in her bibliography. References to species proposed since 1958 are included in the present paper.
- 2. The habitat and relative abundance of species found at Bahías Gonzaga and Willard are given. The species referred to as beach shells were not found living by us. The bathymetric ranges given by KEEN (1958) indicate many of these species live in deeper water.
- 3. The collecting stations referred to in the list by numbers are shown on the accompanying Map.
- 4. Range extensions are indicated by asterisks (\*) following the Keen numbers. The area from which the range is extended follows the collector's initial.
- 5. The following collectors are designated by initials:  
Joseph and Helen DuShane ..... D  
Faye B. Howard ..... H  
Homer P. King ..... K  
James R. Lance ..... L  
James H. McLean ..... M  
Gale Sphon ..... S

The specimens collected by Howard, King and Sphon are in the Santa Barbara Museum of Natural History. The DuShanes and Lance maintain private collections. Specimens collected by McLean are in the Los Angeles County Museum of Natural History.

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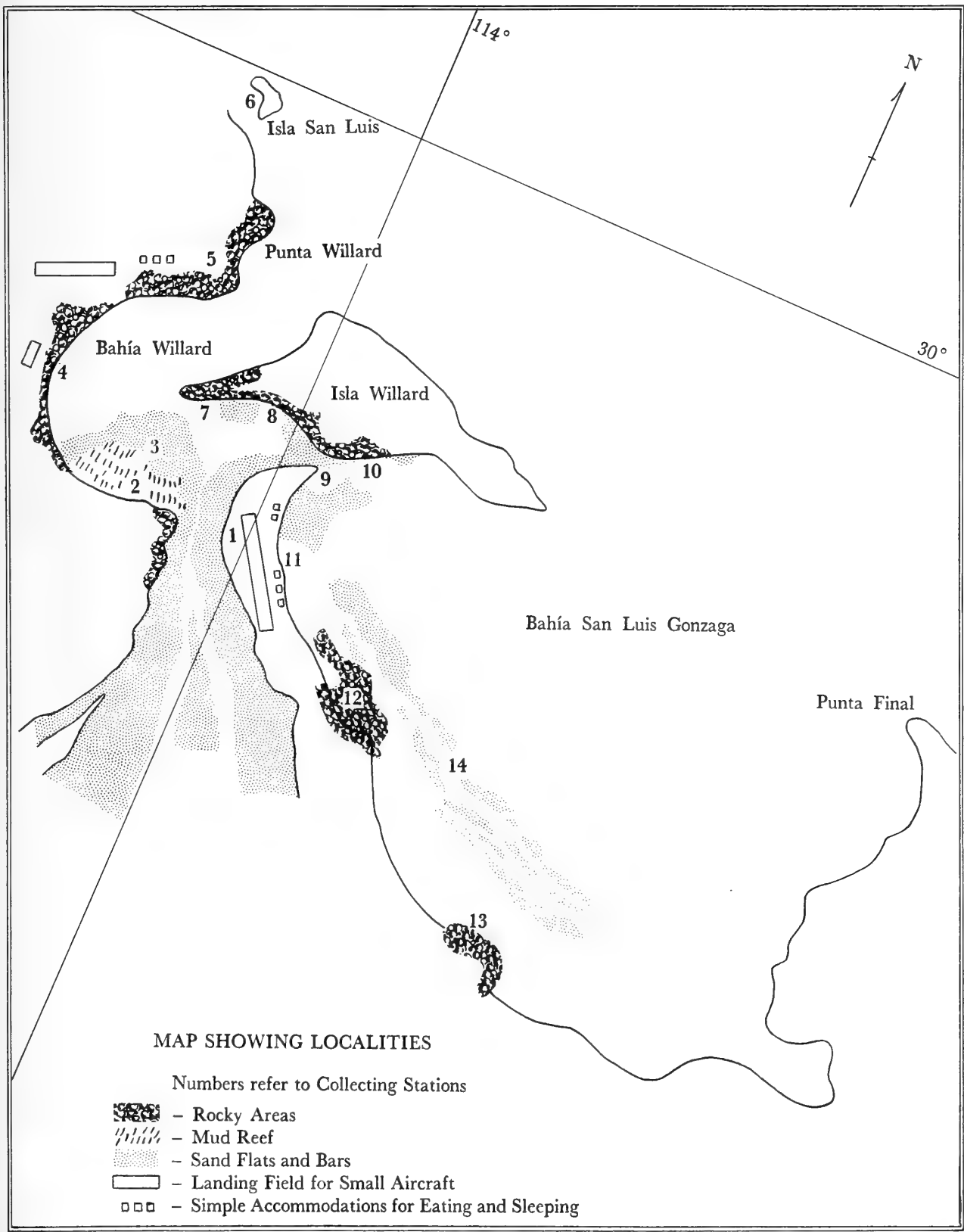
#### ECOLOGICAL NOTES ON FOURTEEN COLLECTING AREAS

(see Map)

1. A low lying drainage channel bordered by *Salicornia*: two species of *Melampus* are in the mud at the roots of these plants.
2. A flat mud covered rock shelf: *Crassispira nymphia* and *C. pluto* are abundant. Large specimens of *Lithophaga attenuata* have bored into the rock.
3. Silty mud flats in the southern half of Willard Bay: *Laevicardium elatum*, *Oliva* spp., *Conus* spp., *Nassarius* spp., *Polinices* spp., and *Cassis ientiquadrata* are common. *Heterodonax bimaculata* is abundant in the upper littoral zone.
4. Rocky shore line with turnable rocks: *Barbatia*, *Lima*, *Crucibulum*, *Murex*, and *Strombus* are common.
5. Rocky shore in an exposed area: only the hardier forms are found, such as *Acmaea*, chitons, and *Acanthina*. Specimens of *Cypraea cervinetta* have been taken here. *Coralliophila costata* and *Modulus disculus* are on the rocks.
6. The largest of a six-island archipelago. Limited dredging here has corroborated the report of the 1921 expedition of the California Academy of Sciences to Isla San Luis.
7. A sheltered cove interspersed with boulders and sandy beaches: *Pecten circularis* and *Lima tectrica* are under and around the rocks. *Ostrea palmula* is attached to the rocks in the high intertidal zone.
8. The south side of Willard Island: this is a protected, rocky shore line with small to medium sized rocks broken by a few flat mud areas. The underside of rocks is an excellent location for nudibranchs, chitons, and *Mitra solitaria*. *Pteropurpura erinaceoides* and *Cymatium gibbosum* cling to the rocks at low tide.
9. Sand spit connecting the shore of Gonzaga Bay to Willard Bay and Willard Island: at low tide the spit is exposed, making it possible to walk to the island. At high tide a depth of 4 m of water has been reported. The outgoing tides create shifting sand bars where *Terebra* spp. and *Conus ximenes* are half buried. This is also the area where *Tivela stultorum* has been introduced (SHASKY, 1961; DUSHANE, 1966).
10. The south side of Willard Island, east of the sand spit and fronting on Gonzaga Bay: a rocky precipitous shore line with rough water. *Opalia diadema*, *Tenaturris carissima* and *Mitra solitaria* are under rocks. *Acmaea turveri* are attached to rocks in the upper littoral, while *A. strongiana* and *Nomaeopelta dalliana* are on the rocks in the mid-tide zone.
11. A steep beach which is actually a continuation of the sand spit: not particularly productive, although *Laevicardium elatum* and *Dosinia ponderosa* are common.
12. A rock reef area with tide pools: the tide pools occur in the upper intertidal zone. *Crucibulum imbricatum*, *Anadara multicostata*, and *Haminoea strongi* are common.
13. A rocky headland with medium size rocks: *Cypraea annettae*, *Arcopsis solida*, and *Isognomon chemnitzianus* are under and attached to rocks.
14. A sand bar area parallel to numbers 12 and 13: this is the low intertidal zone with extensive sand bars. *Cassis centiquadrata*, *Oliva spicata*, and *Terebra variegata* are abundant.

#### PELECYPODA

- 36 *Arca mutabilis* (SOWERBY, 1833). Common (5), under rocks (H, K, S).
- 37 *Arca pacifica* (SOWERBY, 1833). Uncommon (4, 5, 7), adhering to underside of rock ledge, low intertidal zone (H, K).
- 38\* *Barbatia lurida* (SOWERBY, 1833). Uncommon (10), attached to underside of rocks; Espíritu Santo Island, Gulf of California (K, M).
- 39 *Barbatia bailyi* (BARTSCH, 1931). Rare (10), beach specimen (H).
- 40\* *Barbatia gradata* (BRODERIP & SOWERBY, 1829). Uncommon (5), attached to underside of rocks; Scammon's Lagoon, Lower California to Peru (K).
- 43 *Barbatia reeveana* (ORBIGNY, 1846). Common (4, 5, 7, 8), attached between rocks (D, H, K, M, S).
- 44 *Barbatia illota* (SOWERBY, 1833). Uncommon (4, 8, 10), attached to rocks (D, H, K).



- 46 *Arcopsis solida* (SOWERBY, 1833). Common (5, 13), attached to underside of rocks (D, H, K, M, S).
- 57 *Anadara multicostata* (SOWERBY, 1833). Common (4, 12, 13), between rocks in low intertidal zone (D, K, S).
- 60\* *Anadara cepoides* (REEVE, 1844). Rare, beach specimen; Cerralvo Island, Gulf of California to Panama (H).
- 69\* *Noetia reversa* (SOWERBY, 1833). Rare (3); beach specimen; Concepcion Bay, Gulf of California to Peru (K).
- 72 *Glycymeris bicolor* (REEVE, 1843). Rare (3, 10), lying free in sandy runnels (D, H, M).
- 74 *Glycymeris gigantea* (REEVE, 1843). Rare alive, beach valves common (3), partially buried on silty mud flats (H, K, S).
- 75 *Glycymeris maculata* (BRODERIP, 1832). Common (3, 9, 11, 14), partially buried on sand bars (D, H, K, M, S).
- 76 *Glycymeris multicostata* (SOWERBY, 1833). Uncommon (3), partially buried on sand flats (H, K).
- 77 *Glycymeris tessellata* (SOWERBY, 1833). Rare (3), partially buried on silty mud flats (S).
- 83 *Hormomya adamsiana* (DUNKER, 1857). Common (7, 8), attached to underside of rocks (H, S).
- 86\* *Mytella speciosa* (REEVE, 1857). Rare (11), buried in sandy runnel; Magdalena Bay to Peru (D).
- 88 *Crenella divaricata* (ORBIGNY, 1853). Rare; beach specimen (H).
- 90 *Lithophaga aristata* (DILLWYN, 1817). Common (5), boring in rock (H, K).
- 91\* *Lithophaga attenuata* (DESHAYES, 1836). Common (2, 5), boring in mud-covered rock ledge; Costa Rica to Chile (D, K, S).
- 95 *Lithophaga spatiosa* (CARPENTER, 1856). Common (2), boring in mud-covered rock ledge (S).
- 99\* *Gregariella denticulata* (DALL, 1871). Common (8), boring in soft rock; Acapulco, Mexico (H).
- 101 *Modiolus capax* (CONRAD, 1837). Common (2), on mud-covered rock ledge (S).
- 107 *Pteria sterna* (GOULD, 1851). Rare; beach specimen (H).
- 111 *Pinna rugosa* SOWERBY, 1855. Uncommon (4, 5), among rocks, low intertidal zone (K).
- 115 *Isognomon chemnitzianus* (ORBIGNY, 1853). Common (7, 8, 10, 13), attached to underside of rocks (H, K, M, S).
- 124 *Ostrea palmula* CARPENTER, 1857. Common (4, 7), attached to rocks in the high intertidal zone (K, S).
- 126 *Pecten vogdesi* ARNOLD, 1906. Rare living, beach valves common (3), on sand and gravel flats (D, H).
- 128 *Aequipecten palmeri* (DALL, 1897). Rare; beach specimen (H).
- 132 *Aequipecten circularis* (SOWERBY, 1835). Uncommon (5, 7, 8), around and under rocks intertidally (D, H, K, S).
- 137 *Lyropecten subnodosus* (SOWERBY, 1835). Rare (5, 7), among small rocks (H, K, S).
- 140 *Lima tetrica* GOULD, 1851. Rare (4, 7), under rocks (D, H, K).
- 141 *Lima hemphilli* HERTLEIN & STRONG, 1946. Rare (4, 7), under rocks (H, K).
- 146 *Spondylus calcifer* CARPENTER, 1857. Uncommon (5), on rocks (K).
- 147 *Plicatula anomioides* KEEN, 1958. Uncommon (5), under rocks (H, K).
- 152 *Anomia peruviana* ORBIGNY, 1846. Rare (4), on rocks (K).
- 162 *Cardita affinis* SOWERBY, 1833. Common (3, 4, 10), under rocks and on silty mud flats (D, H, K, M, S).
- 163 *Cardita crassicostata* (SOWERBY, 1825). Rare (7, 8), among rocks on Willard Island, intertidally (D, K, S).
- 186 *Lucina lingualis* CARPENTER, 1864. Rare; valves only (H).
- 200 *Codakia distinguenda* (TRYON, 1872). Uncommon (5), in very shallow water at low tide (H, K).
- 205 *Ctena mexicana* (DALL, 1901). Common (14), lying on sand bars (H, S).
- 206 *Divalinga eburnea* (REEVE, 1850). Uncommon (14), partially buried on sand bars (H).
- 210 *Diplodonta subquadrata* CARPENTER, 1856. Common (10), among rocks (M, S).
- 212 *Diplodonta sericata* (REEVE, 1850). Common (3), on mud flats at edge of sting ray basins (D, H, S).
- 213 *Diplodonta caelata* (REEVE, 1850). Rare (2), in pholad holes (H).
- 214 *Diplodonta semirugosa* DALL, 1899. Rare (3), on mud flats (D, S).
- 217 *Aligena nucea* DALL, 1913. Rare; single worn valve (H).
- 224\* *Lasaea subviridis* DALL, 1899. Rare; in the coils of a vermetid; Shelter Cove, California to Cape San Lucas, Lower California (H).
- 236 *Solecardia eburnea* CONRAD, 1849. Uncommon (14), on sand bars (D).
- 238 *Chama buddiana* C. B. ADAMS, 1852. Common (4, 5, 7), attached to rocks (H, K, S).
- 240a\* *Chama frondosa mexicana* CARPENTER, 1857. Uncommon (2), on mud covered rock reef; Guaymas to Panama and Ecuador (D, H, S).
- 243 *Chama venosa* REEVE, 1847. Uncommon (8), on rocks (H).

- 247\* *Pseudochama panamensis* (REEVE, 1847). Uncommon (5), on rocks; Panama (H, K).
- 248 *Pseudochama saavedrai* HERTLEIN & STRONG, 1946. Uncommon (4), on rocks (K).
- 252 *Trachycardium panamense* (SOWERBY, 1833). Common (3, 14), on silty mud flats and sand bars (D, H, K, S).
- 255 *Papyridea aspersa* (SOWERBY, 1833). Common (3), on silty mud flats (D, H, K, S).
- 256 *Trigoniocardia granifera* (BRODERIP & SOWERBY, 1829). Rare (14), partially buried on sand flats (S).
- 258 *Trigoniocardia biangulata* (BRODERIP & SOWERBY, 1829). Common (3, 11, 12, 13), on sand flats and along sand beach (D, H, K, S).
- 262 *Laevicardium elatum* (SOWERBY, 1833). Common (3, 10, 11, 12, 13, 14), rolling in on low tide and partially buried in sand (D, H, K, M, S).
- 263 *Laevicardium elenense* (SOWERBY, 1840 [? 1841]). Common (3, 14), on silty mud flats and on sand bars (D, H, K, S).
- 280 *Transennella puella* (CARPENTER, 1864). Uncommon (8, 9, 10), sand flats (M, S).
- 282 *Transennella tantilla* (GOULD, 1853). Uncommon; under rocks (S).
- 284\* *Pitar consanguineus* (C. B. ADAMS, 1852). Rare; valves only; Port Guatulco, Mexico (H).
- 286 *Pitar newcombianus* (GABB, 1865). Uncommon (3), on silty mud flats (H).
- 303 *Megapitaria squalida* (SOWERBY, 1835). Common (3, 9, 10, 13), partially buried on sand bars (D, H, K, M, S).
- 305 *Dosinia dunkeri* (PHILIPPI, 1844). Uncommon (14), partially buried in sand bars (H, K).
- 306 *Dosinia ponderosa* (GRAY, 1838). Common (14), partially buried in sand bars (D, H, K, S).
- 318 *Chione californiensis* (BRODERIP, 1835). Common (3, 9), on silty mud flats and sand bars (D, M).
- 319 *Chione compta* (BRODERIP, 1835). Uncommon (3), partially buried on mud flats and in runnels (D).
- 320 *Chione guatulcoensis* HERTLEIN & STRONG, 1948. Uncommon; on silty mud flats (D).
- 321 *Chione undatella* (SOWERBY, 1835). Uncommon (11, 12), on sand beach (D, H).
- 328 *Chione purpurissata* DALL, 1902. Rare (9, 10), partially buried on sand beach (D, M).
- 335 *Chione picta* WILLETT, 1944. Uncommon (8), among rocks (S).
- 337 *Anomalocardia tumens* (VERRILL, 1870). Rare (9, 11), on sand beach (D, H).
- 340 *Protothaca grata* (SAY, 1831). Common (3), silty mud flats (K).
- 341 *Protothaca asperrima* (SOWERBY, 1835). Uncommon (3), silty mud flats (S).
- 347 *Petricola denticulata* SOWERBY, 1834. Common (2), boring in soft, rocky ledges (D, H, K).
- 355 *Mactra dolabriformis* (CONRAD, 1867). Uncommon (14), partially buried on sand bars (S).
- 408 *Tellina pristiphora* DALL, 1900. Rare; beach specimens (K).
- 422\* *Apolymetis cognata* (PILSBRY & VANATTA, 1902). Rare; beach specimens; Nicaragua (H).
- 423 *Apolymetis cognata clarki* DURHAM, 1950. Rare; beach specimens (H).
- 450 *Donax gracilis* HANLEY, 1845. Common (14), partially buried on sand bars (D, S).
- 455 *Donax punctatostriatus* HANLEY, 1843. Uncommon (14), on sand bars (H).
- 466 *Gari regularis* (CARPENTER, 1864). Uncommon (11), sand beach (D, H, S).
- 467 *Heterodonax bimaculatus* (LINNAEUS, 1758). Common (3, 10, 12, 13), high tide zone, sand beach (D, H, K, M, S).
- 471 *Tagelus californianus* (CONRAD, 1837). Uncommon (3), silty mud flats (K).
- 475 *Tagelus politus* (CARPENTER, 1857). Rare (3), on silty mud flats (D, H).
- 477 *Semele bicolor* (C. B. ADAMS, 1852). Rare; beach specimen (H).
- 481 *Semele flavescens* (GOULD, 1851). Uncommon (10), among rocks (H, M).
- 483 *Semele guaymasensis* PILSBRY & LOWE, 1932. Rare (8), around rocks (S).
- 489 *Semele pacifica* DALL, 1915. Rare; beach specimens (H).
- 508 *Cumingia lamellosa* SOWERBY, 1833. Uncommon (6, 12, 13), among rocks (D, H, S).
- 512 *Solen mexicanus* DALL, 1899. Uncommon (3), silty mud flats (H).
- 521 *Sphenia fragilis* (H. & A. ADAMS, 1854) (*teste* KEEN). Rare (8), under rocks (S).
- 523 *Corbula bicarinata* SOWERBY, 1833. Uncommon (7), under rocks (D, S).
- 542 *Hiatella arctica* (LINNAEUS, 1767). Common (4, 5, 7, 8), under rocks (H, K, S).
- 578 *Lyonsia gouldii* DALL, 1915. Rare (9), partially buried on sand spit (H).
- 590 *Thracia squamosa* CARPENTER, 1856. Rare (2), in pholad holes (H).
- 593 *Cyathodonta dubiosa* DALL, 1915. Rare; beach specimen (H).
- 594 *Cyathodonta lucasana* DALL, 1915. Rare; beach specimen (H).
- 595 *Cyathodonta undulata* CONRAD, 1849. Rare; beach specimen (H).

## GASTROPODA

- 10 *Acmaea semirubida* DALL, 1914. Rare (3), intertidally, attached to dead *Cardita crassirostrata* (SOWERBY, 1825); dredged 11 m, common (6), (D).
- 12a *Acmaea strongiana* HERTLEIN, 1958. Common (8, 10), on rocks at midtide zone (D, H, M, S).
- 14 *Acmaea turveri* HERTLEIN & STRONG, 1951. Common (8), on rocks in high intertidal zone (D, H, S).
- 16 *Nomaeopelta dalliana* (PILSBRY, 1891). Common (7, 8), on rocks at midtide zone (D, H, K, S).
- 18 *Nomaeopelta stanfordiana* (BERRY, 1957). Rare (8, 10), beach specimens (H, M).  
*Lucapinella milleri* BERRY, 1959 (p. 109). Uncommon (8), attached to underside of rocks (D, H).
- 30 *Diodora alta* (C. B. ADAMS, 1852). Uncommon (7, 8), under rocks (D, H, S).
- 32 *Diodora inaequalis* (SOWERBY, 1835). Common (5, 7, 8, 10), under rocks (D, H, K, M, S).
- 32a *Diodora digueti* MABILLE, 1895. Uncommon (5, 7, 8), under rocks (D).
- 34 *Diodora saturnalis* (CARPENTER, 1864). Rare; beach specimen (H).  
*Diodora pusilla* BERRY, 1959 (p. 109). Common (6), dredged 7 fms. (D).
- 38 *Calliostoma* cf. *C. angelenum* LOWE, 1935. Rare; beach specimen (H).
- Tegula* sp. Under rocks (8, 10), common (H, M, S).
- 54 *Tegula mariana* DALL, 1919. Common (8, 10), under and around rocks (H, M).
- 58 *Tegula rugosa* (A. ADAMS, 1853). Common (5, 7, 8, 10, 12, 13), on rocks (D, H, K, M, S).
- 64 *Turbo fluctuosus* WOOD, 1828. Uncommon (8, 10), among rocks (H, K, M).
- 68 *Turbo squamiger* REEVE, 1843. Uncommon (6), dredged in 11 m (D).  
*Tricolia typica* (DALL, 1908). Common (6), dredged in 11 m (D).
- 81 *Nerita scabricosta* LAMARCK, 1822. Rare (5), on rocks (H).
- 82 *Nerita funiculata* MENKE, 1851. Common (5, 8, 10), on rocks in high tide area (H, M, S).
- 83 *Neritina luteofasciata* MILLER, 1879. Uncommon (3), in runnels on silty mud flat (H).
- 87 *Niso excolpa* BARTSCH, 1917. Beach specimen (D).
- 90 *Epitonium acapulcanum* DALL, 1917. Uncommon (7), on *Cardita crassirostrata* (SOWERBY, 1825) (D).
- 124 *Epitonium oerstedianum* HERTLEIN & STRONG, 1951. Beach specimen (H).
- 158 *Opalia diadema* (SOWERBY, 1832). Uncommon (10), under rocks on west side of Willard Island (D, H).
- 175a *Littorina dubiosa penicillata* CARPENTER, 1864. Common (7), on rocks (H).

## Explanation of Plate 35

Figure 1a, 1b: *Cyclostrema spiceri* BAKER, HANNA & STRONG, 1938. Holotype, California Academy of Sciences Paleo. Type Collection 5462 (x 15.5). Greatest diameter 3.97 mm; least diam. 2.93 mm; alt. 2.2 mm. Type locality: Coyote Bay, Concepcion Bay, Lower California, Mexico, in about 2 fathoms.

Figure 2: *Terebra berryi* CAMPBELL, 1961. Holotype: Calif. Acad. Sci. Paleo. Type Coll. 12352 (x 2). Length 32 mm; width 7 mm. Type locality: Puertecitos, Lower California, Mexico.

Figure 3: *Triphora hannai* BAKER, 1926. Holotype, Calif. Acad. Sci. Paleo. Type Coll. 2136 (x 10). Length 8.17 mm; diam. 2.43 mm. Type locality: San Francisco Island, Gulf of California, Mexico.

Figure 4: *Lamellaria sharonae* WILLET, 1939. Holotype: Los Angeles County Mus. Nat. Hist. 1059 (x 3.5). Max. diam. 5.5 mm; alt. 7.4 mm. Type locality: Anaheim Bay, Orange County, California.

Figure 5: *Diodora pusilla* BERRY, 1959. Holotype: Stanford Univ. Paleo. Type Coll. 8587 (x 3). Long. 3.8 mm; lat. 2.5 mm; alt. 3.6 mm. Type locality: 6-10 fathoms, off Acapulco, Guerrero, Mexico.

Figure 6: *Retusa gonzagensis* BAKER & HANNA, 1927. Holotype: Calif. Acad. Sci. Paleo. Type Coll. 2519 (x 9). Length 2.9 mm; diam. 1.6 mm. Type locality: San Luis Gonzaga Bay, Gulf of California, Mexico.

Figure 7: *Lucapinella milleri* BERRY, 1959. Holotype: Stanford Univ. Paleo. Type Coll. 8588 (x 3.5). Long. 8.6 mm; lat. 4.6 mm; alt. 1.4 mm; diam. of foramen at center 1.3 mm. Type locality: Puertecitos, Lower California, Mexico.

Figure 8: *Melampus mousleyi* BERRY, 1964. Holotype: Stanford Univ. Paleo. Type Coll. 9503 (x 3). Alt. 10 mm; diam. 5.4 mm. Type locality: Cholla Cove, Bahía de Adair, Sonora, Mexico.

Figure 9a, 9b: *Aspella bakeri* HERTLEIN & STRONG, 1951. Holotype: Calif. Acad. Sci. Paleo. Type Coll. 5893 (x 1.3). Length 18 mm; diam. 8 mm. Type locality: Agua Verde Bay, Gulf of California, Mexico.

Figure 10: *Epitonium oerstedianum* HERTLEIN & STRONG, 1951. Holotype: Calif. Acad. Sci. Paleo. Type Coll. 9622 (x 8). Length 6.5 mm; diam. 4.2 mm. Type locality: Off San Domingo Point, Santa Inez Bay, Gulf of California, Mexico.

Figure 11: *Coralliophila incompta* BERRY, 1960. DuShane Coll. Length 23 mm; diam. 14 mm. Holotype: Berry Coll. 18768; length 33.5 mm; diam. 20.3 mm. Type locality: Puerto Refugio, Angel de la Guarda Island, Gulf of California, Mexico.

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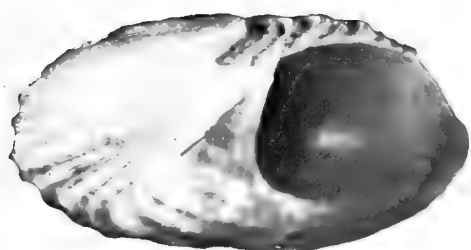


Figure 1 a



Figure 1 b



Figure 2

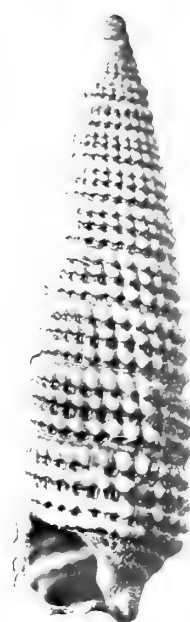


Figure 3



Figure 4

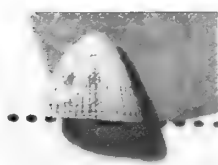


Figure 5



Figure 6

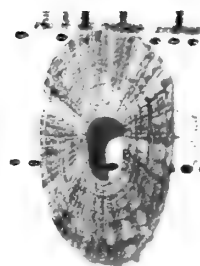


Figure 7



Figure 8

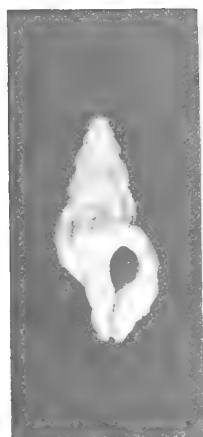


Figure 9 a

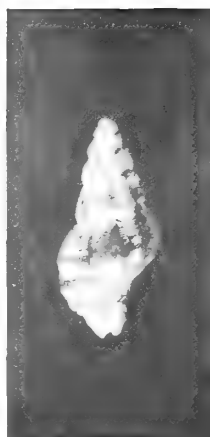


Figure 9 b



Figure 10

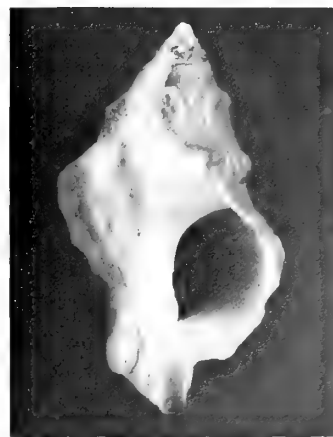


Figure 11



- \* *Cyclostrema spiceri* BAKER, HANNA & STRONG, 1938 (p. 234). Beach specimen (10); Concepcion Bay, Gulf of California (M).  
*Truncatella bairdiana* (C. B. ADAMS, 1852) (p. 437). Uncommon (8, 10), under rocks on west side of Willard Island (D, H, M, S).
- \* *Rissoina burragei* BARTSCH, 1915 (p. 28). Uncommon (8, 10), under rocks; Los Angeles Bay, Gulf of California (McLEAN, 1961), (D, M, S).
- \* *Rissoina barthelowi* BARTSCH, 1915 (p. 28). Dredged in 11 m (6); Concepcion Bay, Gulf of California and Guaymas, Mexico (DuSHANE & POORMAN, 1967), (D).
- \* *Rissoina stricta* (MENKE, 1850) (p. 161). Dredged in 11 m (6); Guaymas, Mexico (DuSHANE & POORMAN, 1967), (D).
- \* *Rissoina zeltneri* DEFOLIN, 1867. Rare, Beach specimens; Panama (H).
- \* *Alvania monserratensis* BAKER, HANNA & STRONG, 1930 (p. 27). Beach specimens; Monserrate Island, Gulf of California (H).
- \* *Barleeia polychroma* (DEFOLIN, 1870). Rare (8), under rocks; Panama (H).
- 185 *Turritella leucostoma* VALENCIENNES, 1832. Rare (11), beach specimens (H).
- 189a *Vermicularia pellucida eburnea* (REEVE, 1842). Common (7, 8, 10, 11, 12, 13), under rocks (D, H, S).
- 193 *Helicacis bicanaliculatus* (VALENCIENNES, 1832). Uncommon (3, 5), on muddy sand reef and among compound ascidians in low intertidal zone (D, H, K).  
*Caecum* sp. Rare, attached to live *Cardita crassicotata* (SOWERBY, 1825), (D).
- \* *Elephantulum liraticincta* (CARPENTER, 1857) (p. 317). Uncommon (8), in sand; Panama (D, S).
- \* *Elephantanellum heptagonum* (CARPENTER, 1857) (p. 319). Uncommon (8), in sand; Bahía de Los Angeles, Gulf of California (D, S).
- 196 *Modulus cerodes* (A. ADAMS, 1851). Rare (3, 8, 12), on silty mud flats and among rocks (D, H, K).
- 197 *Modulus disculus* (PHILIPPI, 1846). Common (3, 5, 8, 12, 13), on silty mud flats and among rocks (D, H, K, M, S).
- 198 *Vermetus centiquadrus* VALENCIENNES, 1846 (*teste* KEEN). Uncommon (8), under rocks (H).
- 199\* *Petalconchus* cf. *P. complicatus* DALL, 1908. Common (5), on rock; Cocos Island, Panama (H).
- 200a\* *Petalconchus flavescens* (CARPENTER, 1857). Common (5), on rocks; Guaymas to Mazatlan, Mexico (H).
- 201 *Vermetus indentatus* (CARPENTER, 1856), (*teste* KEEN). Common (5), on rocks (H).
- 203 *Petalconchus macrophragma* CARPENTER, 1865. Beach specimen (H).
- 204 *Serpulorbis* cf. *S. eruciformis* (MÖRCH, 1862). Rare (8), on rocks (H).
- 208 *Vermetus tripsycha* PILSBRY & LOWE, 1932. Uncommon (8), on rocks (H).
- 214 *Cerithium sculptum* SOWERBY, 1855. Common (4, 5, 10), around rocks (H, K, M).
- 215 *Cerithium stercusmuscarum* VALENCIENNES, 1833. Common (10), around rocks (H).
- 216 *Cerithium uncinatum* (GMELIN, 1791). Rare (8), around rocks in low intertidal zone (D).
- \* *Triphora hannai* BAKER, 1926 (p. 225). Dredged in 11 m (6); San Francisco Island, Gulf of California (D).
- \* *Triphora oweni* BAKER, 1926 (p. 232). Dredged in 11 m (6); San Francisco Island, Gulf of California (D).
- \* *Triphora panamensis* (BARTSCH, 1907) (p. 249). Rare (8), under rocks; Panama (S).  
*Metaxia convexa* (CARPENTER, 1857) (p. 444). Dredged in 11 m (6), (D).  
*Seila assimilata* (C. B. ADAMS, 1852) (p. 374). Uncommon (8), under rocks (H, S).
- \* *Alaba interruptilineata* PILSBRY & LOWE, 1932 (p. 81). Uncommon (8, 10), under rocks (see McLEAN 1961; DuSHANE 1962), (D, M, S).
- \* *Alaba supralirata* CARPENTER, 1857 (p. 366). Rare (8), under rocks; Bahía de Los Angeles, Gulf of California (H).  
*Alabina diomedea* (BARTSCH, 1911) (p. 413). Uncommon (7, 10), under rocks (D, M, S).
- \* *Alabina monicensis* (BARTSCH, 1911) (p. 409). Uncommon (7, 10), under rocks; Santa Monica, California (S).  
*Alabina tenuisculpta* (CARPENTER, 1864) (p. 517). Uncommon (7, 10), under rocks (S).
- 220 *Cerithidea mazatlanica* CARPENTER, 1857. Common (1), under *Salicornia* bushes on mud flats (D, H, K, M, S).
- 224 *Rhinocoryne humboldti* (VALENCIENNES, 1832). Rare, beach specimens (H).
- 227 *Hipponix pilosus* (DESHAYES, 1832). Uncommon (5), on rocks (H).
- 229 *Hipponix serratus* CARPENTER, 1857. Rare (10), beach specimens (H, M).
- 233 *Calypttraca mamillaris* BRODERIP, 1834. Uncommon (3), beach specimens (H).
- 240 *Crepidula arenata* (BRODERIP, 1834). Common (8), attached to rocks (H, S).
- 241 *Crepidula excavata* (BRODERIP, 1834). Common (7, 8), attached to rocks and shells (S).

- 242 *Crepidula incurva* (BRODERIP, 1834). Common (3, 10, 13), living on other shells (H, S).
- 243 *Crepidula lessonii* (BRODERIP, 1834). Uncommon (8, 12), under rocks (S).
- 245 *Crepidula onyx* SOWERBY, 1824. Common (3, 5, 10, 13), on beach shells (H, K, M, S).
- 248 *Crepidula striolata* MENKE, 1851. Common (5), living on other shells (H, K).
- 252 *Crucibulum scutellatum* (WOOD, 1828). Common (3, 4, 12, 13), attached to rocks (D, H, K, S).
- 254 *Crucibulum spinosum* (SOWERBY, 1824). Common (4, 7, 10, 12, 13), attached to rocks (D, H, K, M, S).
- 258 *Natica chemnitzii* PFEIFFER, 1840. Common (3, 12, 14), on silty mud flats and sand bars (D, H, K, S).
- 266 *Polinices bifasciatus* (GRAY, 1834). Common (3, 10, 14), on silty mud flats and sand bars (D, H, K, M, S).
- 272 *Polinices uber* (VALENCIENNES, 1832) Common (3, 10, 14), on silty mud flats and sand bars (D, H, K, M, S).
- 274 *Polinices reclusianus* (DESHAYES, 1839). Common (3, 4, 9, 14), on silty mud flats and sand bars (D, K, S).
- 275 *Sinum debile* (GOULD, 1853). Rare (3), partially buried on silty mud flat (S).
- 276\* *Sinum noyesii* DALL, 1903. Rare (3), partially buried on silty mud flat; Nicaragua to Panama (S).
- 280 *Lamellaria inflata* (C. B. ADAMS, 1852). Common (8), under rocks (D, S).
- \* *Lamellaria sharonae* WILLETT, 1939 (p. 123). Rare (8), under rocks; Anaheim Bay, Orange County, California (S). Original spelling *L. "sharoni"* emended by BURCH (1946) to *L. sharonae*.
- 283 *Cypraea cervinetta* KIENER, 1843. Under rocks (5), [collected by Phillips, Santa Barbara, November, 1966].
- 287 *Cypraea annettae* DALL, 1909. Common (4, 5, 7, 8, 13), attached to underside of rocks (D, H, K, S).
- 289 *Erato columbella* MENKE, 1847. Uncommon (8, 10), attached to underside of rocks (D, H, M, S).
- 296 *Trivia californiana* (GRAY, 1828). Uncommon (5, 7, 8), under and on rocks (H, K, S).
- 297 *Trivia radians* (LAMARCK, 1810). Beach specimens (5, 12), (K).
- 299 *Trivia solandri* (SOWERBY, 1832). Uncommon (5, 7, 8), under and on rocks (H, K, S).
- 300 *Jenneria pustulata* (LIGHTFOOT, 1786). Uncommon (5, 8), under rocks (H, K, S).
- 307 *Strombus galeatus* SWAINSON, 1823. Uncommon (4, 8), in sand next to rocks (H, K, S).
- 308 *Strombus gracilior* SOWERBY, 1825. Uncommon (3, 4, 11, 12), partially buried in sand (D, H, K, S).
- 309 *Strombus granulatus* SWAINSON, 1822. Common (3, 4, 7, 10), on silty mud flats and around rocks (D, H, K, M, S).
- 315 *Cassis centiquadrata* (VALENCIENNES, 1832). Uncommon (3, 14), on silty mud flats and sand bars (D, H, K, S).
- 324 *Cymatium gibbosum* (BRODERIP, 1833). Uncommon in February, common in late spring and early summer (4, 5, 7, 8, 12, 13), on rocks (D, H, K, S).
- 335 *Murex elenensis* DALL, 1909. Uncommon (3, 4, 5), on rocks (H, K, S).
- 339 *Hexaplex erythrostomus* (SWAINSON, 1831). Uncommon in February, common in May (3, 4, 5), on silty mud flats and around rocks (D, H, K, S).
- 344 *Muricanthus nigrilus* (PHILIPPI, 1845). Uncommon in February, common in May (3, 5), on tidal flats and among rocks (D, H, K, M, S).
- 348 *Pteropurpura erinaceoides* (VALENCIENNES, 1832). [see EMERSON, 1964, p. 5]. Common (5, 7, 8, 12, 13), on top and sides of rocks (D, H, K, S).
- 375\* *Aspella bakeri* HERTLEIN & STRONG, 1951. Dredged in 11 m (6); Agua Verde Bay, Gulf of California (D).
- 387 *Coralliophila costata* (BLAINVILLE, 1832). Uncommon (2, 5, 12, 13), on top of rocks (D, K).
- 388 *Coralliophila hindsii* (CARPENTER, 1857). Rare (5), on rocks (H).
- Coralliophila incompta* BERRY, 1960. Uncommon (6); 11 m (D).
- 398 *Thais biserialis* (BLAINVILLE, 1832). Common (4, 5, 7, 8, 12, 13), on rocks (D, H, S).
- 404 *Acanthina angelica* I. OLDROYD, 1918. Common (4, 5, 7, 8, 10, 12, 13), on rocks at high tide level (D, K, M, S).
- 409 *Acanthina tuberculata* (SOWERBY, 1835). Common (4, 5, 7, 8, 10, 12, 13), on rocks (D, H, K, M, S).
- 411 *Morula ferruginosa* (REEVE, 1846). Common (7, 8, 10, 12, 13), intertidally under rocks (D, H, M, S).
- 412 *Morula lugubris* (C. B. ADAMS, 1852). Uncommon (8), intertidally under rocks (H).
- \* *Decipifus gracilis* McLEAN, 1959. Uncommon (8), under rocks; Bahía de los Angeles, Baja California (D, S).
- Decipifus* spec. nov. Uncommon (8), under rocks (D, S).
- 424 *Anachis coronata* (SOWERBY, 1832). Uncommon (5, 8, 10, 13), under rocks; dredged in 11 m, common (6), (D, H, K, M, S).
- 433\* *Anachis* cf. *A. taeniata* PHILIPPI, 1846. Rare, beach specimens; west Mexican coast (H).

- 437 *Anachis hilli* PILSBRY & LOWE, 1932. Rare (8), under rocks on the west side of Willard Island (D).
- 444 *Anachis nigricans* (SOWERBY, 1844). Uncommon (5, 8), under rocks (H, K).
- 464 *Anachis varia* (SOWERBY, 1832). Uncommon (5, 8, 13), under rocks (D, H, K).
- 478 *Mitrella dorma* BAKER, HANNA & STRONG, 1938. Uncommon (8), intertidally under rocks (D, H).
- 482 *Mitrella lalage* PILSBRY & LOWE, 1932. Uncommon (8), intertidally under rocks (S).
- 484 *Mitrella guttata* (SOWERBY, 1832). [see HOWARD, 1963]. Common (4, 5, 7, 8), intertidally under rocks (D, H, M).
- 486 *Mitrella santabarbarensis* (CARPENTER, in GOULD & CARPENTER, 1857). Rare (10), intertidally under rocks (M).
- 490\* *Nassarina pammicra* PILSBRY & LOWE, 1932. Uncommon (8), clustered under rocks at sides of drainage channels; Bahía de Los Angeles, Gulf of California (D, S).
- 494 *Parametaria dupontii* (KIENER, 1849-1850). Uncommon (5, 8), on rocks (H, K).
- Pyrene aureomexicana* HOWARD, 1963. Common (8, 10, 12, 13), under rocks (D, H, M, S).
- 508 *Strombina dorsata* (SOWERBY, 1832). Rare (2), on sandy mud reef (D, S).
- 512 *Strombina gibberula* (SOWERBY, 1832). Rare (2), on mud covered rock reef (S).
- 515 *Strombina maculosa* (SOWERBY, 1832). Common (3, 4, 10), on silty sand flats (D, H, K, M, S).
- 543 *Cantharus macrospira* (BERRY, 1957) (?) as "*Solenosteira anomala*." Common (3), on silty sand flats (D, H, K, S).
- 549 *Engina maura* (SOWERBY, 1832). Rare, beach specimen (H).
- 550a\* *Engina reevei* TRYON, 1883. Rare (8), on rocks; Southern Gulf of California, possibly south to Panama (H).
- 551 *Engina solida* (DALL, 1917). Rare, beach specimen (D).
- 567 *Melongena patula* (BRODERIP & SOWERBY, 1829). Rare (3), juvenile on silty mud flats (S).
- 587 *Nassarius versicolor* (C. B. ADAMS, 1852). Common (10, 14), on sand bars (D, H, M, S).
- 595 *Nassarius tiarula* (KIENER, 1841). Common (10, 14), on sand bars (D, H, M, S).
- 610 *Fusinus dupetitthouarsi* (KIENER, 1846). Rare, beach specimen (H).
- 612 *Fusinus ambustus* (GOULD, 1853). Common (2, 7, 8), on mud covered rock ledge (D, H, S).
- 618 *Fusinus felipensis* LOWE, 1935. Uncommon (8, 10, 13), under rocks (D, M, S).
- 620 *Oliva incrassata* (LIGHTFOOT, 1786). Common (3, 4, 14), partially buried in sand (D, H, K, S).
- 625 *Oliva spicata* (RÖDING, 1798). Common (3, 4, 14), partially buried in sand (D, H, K, S).
- 627 *Oliva undatella* LAMARCK, 1810. Common (11, 12, 13, 14), partially buried in sand bars (D, S).
- 634 *Olivella dama* (WOOD, 1828, ex MAWE MS.). Common (9, 10, 11, 12, 13, 14), partially buried in sand bars (D, H, K, M, S).
- 634a *Olivella fletcheriae* BERRY, 1958. Common (11, 12, 13, 14), partially buried in sand bars (D, K, M, S).
- 645 *Olivella zanoeta* (DUCLOS, 1835). Uncommon (3, 12, 13), partially buried in sand flats (K).
- 646 *Mitra solitaria* C. B. ADAMS, 1858. Uncommon (8, 10), under rocks (D, H, M, S).
- 656 *Mitra tristis* BRODERIP, 1836. Common (2, 5, 12, 13), on mud covered rock reef (D, H, K, M, S).
- 659 *Mitra erythrogramma* TOMLIN, 1931. Uncommon (2), partially buried on sandy, mud covered rock ledge (D, S).
- 666 *Lyria cumingii* (BRODERIP, 1832). Uncommon (3, 4, 12, 13), on mud covered rock shelf (D, H, K, M, S).
- 669 *Volvarina taeniolata* (MÖRCH, 1860). Formerly *Marginella californica* TOMLIN, 1916 [see COAN & ROTH, 1966]. Common (4, 5, 7, 8, 13), under rocks (D, H, K, S).
- 685 *Cancellaria obesa* SOWERBY, 1832. Rare (3, 12), beach specimens (H, K).
- 693 *Cancellaria cassidiformis* SOWERBY, 1832. Rare (3, 12), beach specimens (K, S).
- 710 *Trigonostoma goniostoma* (SOWERBY, 1832). Uncommon (2, 5, 13), on mud covered rock shelf (D, H, K, M, S).
- 726 *Knefastia funiculata* (KIENER, 1839-1840, ex VALENCIENNES MS.). Uncommon, beach specimen (H).
- 727 *Knefastia olivacea* (SOWERBY, 1833). Rare (8), among rubble rocks (H).
- 728 *Knefastia tuberculifera* (BRODERIP & SOWERBY, 1829). Rare (2), on mud covered rock ledge (S).
- 746\* *Clavus aeginus* (DALL, 1919). Rare (6), dredged in 11 m; Agua Verde Bay, Gulf of California (D).
- 753 *Clavus ianthe* (DALL, 1919). Rare, beach specimen (S).
- 767\* *Clathrodrillia maura* (SOWERBY, 1834). Rare, beach specimen; Mazatlan, Mexico (D).
- 770 *Clathrodrillia aenone* (DALL, 1919). Rare (2), on rocky reef (S).
- 807 *Crassispira flavonodosa* PILSBRY & LOWE, 1932. Rare (7), under rocks (D).
- 818\* *Crassispira* cf. *C. monilifera* (CARPENTER, 1857).

- Common (2, 8), on muddy rocky reef and under rocks; Mazatlan, Mexico to Panama (D, S).
- 822 *Crassispira nymphia* PILSBRY & LOWE, 1932. Common (2), on mud covered rocky reef (D, H, M, S).
- 825 *Crassispira pluto* PILSBRY & LOWE, 1932. Common (2), on mud covered rocky reef (D, S).
- 860\* *Mangelia finitima* (PILSBRY & LOWE, 1932). Rare (8, 10), under rocks; Guaymas, Mexico [see DUSHANE & POORMAN, 1967] (D, H, M, S).
- 866 *Mangelia subdiaphana* CARPENTER, 1864. Rare (8), under rocks (S).
- 867 *Mangelia antiochroa* PILSBRY & LOWE, 1932. Rare, beach specimen (H).
- \* *Philbertia scammoni* DALL, 1919. Rare (8), under rocks; Scammon's Lagoon, west coast of Lower California (S).
- 893\* *Tenaturris carissima* (PILSBRY & LOWE, 1932). Rare, beach specimen; Manzanillo, Mexico (M).
- 894 *Tenaturris nereis* (PILSBRY & LOWE, 1932). Rare (8), under rocks (D, H, M, S).
- 908 *Hormospira maculosa* (SOWERBY, 1834). Uncommon (2), on silty mud reef (D, S).
- 913 *Pleuroliria picta* (REEVE, 1843, ex BECK MS.). Dredged in 11 m (6), (D).
- 922 *Conus princeps* LINNAEUS, 1758. Beach specimen (K).
- 930 *Conus ximenes* GRAY, 1839. Common (3, 14), partially buried in sand flats (D, H, K, M, S).
- 931 *Conus mahogani* REEVE, 1843. Uncommon (9), on sand flats (D, S).
- 941 *Conus regularis* SOWERBY, 1833. Rare (3), on silty mud flats (K).
- 955\* *Terebra albocincta* (CARPENTER, 1857). Uncommon (9), sand bar next to Willard Island (coll. DuShane December 1964, Puertecitos) (D, H, K, S).
- 956 *Terebra armillata* HINDS, 1844. Uncommon (9), on sand bars (D, S).
- 980 *Terebra variegata* GRAY, 1834. Common (3, 14), on silty mud flats and sand bars (D, K, S).
- \* *Terebra berryi* CAMPBELL, 1961 (p. 26). Uncommon (9), on sand bar; Puertecitos, Gulf of California [see DUSHANE, 1962] (D, S).
- Terebra dushanae* CAMPBELL, 1964 (p. 135). Rare, beach specimen (H).
- 982 *Bulla gouldiana* PILSBRY, 1895. Uncommon (12), in tide pools (D, H, M).
- 983 *Bulla punctulata* A. ADAMS, in SOWERBY, 1850. Uncommon, beach specimens (H).
- 984 *Haminoea angelensis* BAKER & HANNA, 1927. Beach specimen (H).
- 986 *Haminoea strongi* BAKER & HANNA, 1927. Common (12), in small tide pools around rocks (D, H, S).
- 992 *Acteocina angustior* BAKER & HANNA, 1927. Rare (8), under rocks (S).
- 993\* *Acteocina carinata* (CARPENTER, 1857). Uncommon (8), under rocks; Guaymas, Mexico (DUSHANE & POORMAN, 1967) (S).
- 995 *Acteocina infrequens* (C. B. ADAMS, 1852). Uncommon (8), under rocks (S).
- Retusa gonzagensis* BAKER & HANNA, 1927 (p. 131). Uncommon (8), under rocks [type locality] (S).
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- 9 *Acanthochitona exquisita* (PILSBRY, 1893). Common (7, 8), under rocks (S).
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# Mating Behavior in *Mitra idae* MELVILL, 1893

BY

JEAN M. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

(8 Text figures)

## INTRODUCTION

THE OBSERVATIONS SET FORTH in this paper are the indirect result of an experiment to learn the feeding habits and food preferences of *Mitra* (*Atrimitra*) *idae* MELVILL, 1893 (see Text figure 1). The intended study of foods and feeding in *M. idae* was a complete failure; during the



Figure 1

*Mitra* (*Atrimitra*) *idae* MELVILL, 1893

approximately 8 months of experimentation with various kinds of foods thought likely to tempt the animals, apparently no feeding whatsoever took place. However, the animals seemed unaffected by their apparent long fast and were as active after months of presumed starvation as when they were first collected, although they had not grown during that time, as evidenced by periodic measurements.

Concurrent with the intended experiment, careful notes were taken on the mating behavior of these animals

whenever it was observed, and it is these notes that are the basis for this paper.

## MATERIALS AND METHODS

A 15-gallon marine aquarium was set up on an outdoor patio with a northern exposure. Though completely open to the north, the porch was protected on the other three sides by the walls of the U-shaped house, and was covered by a translucent whitish plastic roof which admitted filtered sunlight on bright days.

Local coarse beach sand, sterilized in an oven at 400° F for one hour, comprised the bottom layer in the tank; this was covered by a layer of finer sterile sand to a total depth of about 3 inches. Sea water drawn from a marine well was filtered through a double layer of heavy filter paper before being added. These precautions were taken in order to prevent any unknown food from obscuring the results of the feeding experiment; in other words, they were the control for the unsuccessful experiment, and were not planned as a part of the mating-behavior observations.

Two filtering systems were used, one a subsurface "Miracle" filter with two outlets, and the other an outside charcoal-and-fiberglass filter with one outlet; in addition two airstones were used to ensure adequate aeration; all this equipment worked off one commercial aquarium pump. A 50-watt heater with a submerged thermostat helped to regulate the temperature; a constant temperature of 12° to 15° C was thus maintained through the winter months, this being the average thermic range in the area where the animals were collected. Approximately the same temperatures were maintained in summer through the use of frozen plastic-jelly "Scotch Ice" blocks. All filters and aeration systems were in operation for 36 hours before the animals were introduced into the tank.

Twenty-six animals, ranging in size from 35.0 mm to 56.9 mm, were placed in the aquarium February 24, 1965. They had been collected by SCUBA divers 10 days previously, in 23 feet of water off Little Dume Point, near Malibu, southern California, and kept in a large holding tank while the experimental aquarium was made ready. The habitat at the collecting grounds was a rocky reef with scattered patches of sand.

All animals were code-marked with an electric drill, following the procedure described by STOHLER (1962). The marks were later painted with white "Snopake" for easy identification during observation. Shell measurements were recorded in the hope that some rate of growth could be ascertained by the time the experiment ended. While the whitened marks did prove helpful in distinguishing the animals from one another during observation, no discernible growth increment in any animal was noted when the experiment was discontinued approximately 8 months later; this fact further seemed to verify that the animals had ingested no food during that period. Most of the animals exuded a purple fluid when they were subjected to work with the dental drill.

## OBSERVATIONS

Although copulation was observed on numerous occasions, the general behavioral pattern was about the same each time; therefore this will be a composite report of the several occasions when mating was observed.

Once or twice I noted attempts at copulation being made at the water line near the filter's air outlet at the upper edge of the aquarium, but the usual place was the sandy floor of the aquarium.

In every instance the female was the larger of two coupled animals. The two most active mollusks were "No. 4," a male whose shell measured 43.45 mm by 14.50 mm, and "No. 8," a female with a shell measuring 56.90 mm by 19.60 mm – the latter being the largest of all the experimental animals. These same two individuals seemed to prefer one another to the other animals; while they were not mutually exclusive, my notes show a repetitive pattern referring to "No. 4" and "No. 8" on several occasions. This pattern does not occur among any other specified individuals. Other coupling pairs, while generally smaller, averaged the same as far as the male-female size ratio is concerned.

All animals seemed to be more or less generally active or dormant at the same times; frequently all would be buried completely out of sight in the substrate for about a week, then their siphons would appear above the sur-

face of the sand for a day or two, and finally all of the animals would climb to every part of the aquarium at once – the most popular place evidently being the area nearest the air outlets at the waterline near the top of the tank. Here they were out of the sea water, but within the spray-zone of the aerator. This was especially interesting behavior in animals usually found in greatest abundance subtidally (see Text figure 2).



Figure 2

Bottom of foot of *Mitra idae* in normal crawling position, as viewed through glass wall of aquarium

It was frequently observed that the periods of greatest activity, especially sex activity, corresponded within minutes to a high tide in Los Angeles Harbor, despite the fact that the animals had been collected from a subtidal habitat. There seemed to be no correlation between the active or dormant periods and the introduction of food items; the animals simply continued whatever they had been doing when food was put into the tank, ignoring the food completely or moving in an other direction to avoid contact with it.

## PRELIMINARY SEX ACTIVITY

The first unusual behavior to be noted, other than the normal moving around in the aquarium, was the exudation of a cloud of clear mucus from one of the larger animals, which later proved to be a female. When occurring up high in the tank at the waterline, this appeared as a mass of tiny clear bubbles trapped in a cloud of clear, colorless mucus roughly the same length as the animal's shell, but sagging somewhat heavily in the water like a small plastic bag full of carbonated water (see Text figure 3). Other, smaller animals quickly gathered around this area, evidently drawn by some powerful attractant; these later proved to be the male individuals. On a few occasions I deliberately moved the male animals as far away as possible from the "bubble-sac;" without exception they responded by moving rapidly back toward the mucus sac (and incidentally toward the female individ-

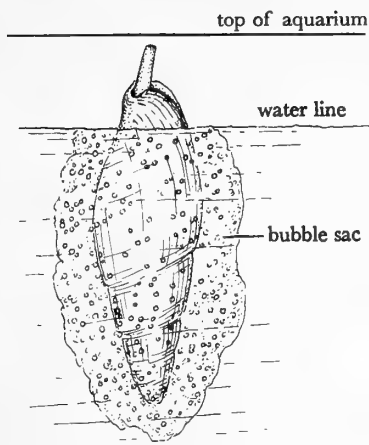


Figure 3

Typical "bubble sac" of female *Mitra idae* seen clinging to aquarium wall at water line

ual), often even taking shorter routes by crawling up and along suspended air-hoses (like walking a tightrope) rather than to take the slower but more normal route of crossing the sand floor and climbing the glass walls of the aquarium. No animals were ever seen to climb along the air-hoses at any time other than when a female was exuding a "bubble-sac." Whatever the attractant was, it seemed to disperse very rapidly to all corners of the aquarium, probably through the currents set up by the filter- and aeration-systems.

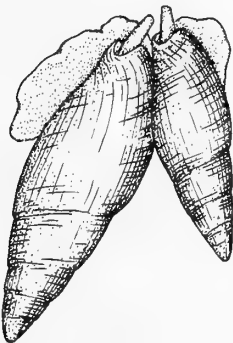


Figure 4

Copulatory positions as viewed from above  
Left, female; Right, male

In the upper corners of the tank at the points where the air outlets emerged and the animals frequently congregated, observations were not easily made due to the position of the tank against a house-wall and the presence of a metal rim on the tank which obscured my view of the animals. It is possible that copulation did sometimes occur at this location (see Text figure 4), but with less success than on the sandy floor of the tank or beneath the substrate. Some animals were seen to drop from the waterline to the floor at times, possibly from the weight of several individuals clinging to one female. At such times no further sexual activity was noted.

At times females could be seen exuding the "bubble sac" while at rest on the substrate. The first noticeable action would be for the female to stand erect, with foot fully extended and shell raised high so that a large portion of the body above the foot could be seen – apparently an unusual position except at times of pre-sexual activity (see Text figure 5). This upper body area seemed

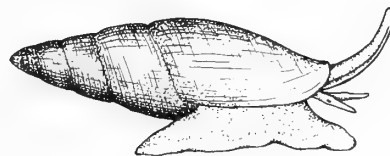


Figure 5

Typical female of *Mitra idae* in what is apparently a "courtship" position. Note the swollen body, elevated shell, and extended siphon

tumid, swollen and more translucent than the solid milk-white color usually observed in an animal at rest; it also exhibited a pale pinkish color that seemed almost a blush originating deep inside the body.

It is possible that the attractant material would first be released at about this stage, for it was noted that several of the other animals would become active, extending their siphons far longer than normal, actively searching and testing the water – both males and females. Males moved fairly rapidly toward the performing individual. After remaining in this position for a period of about 5 to 10 minutes, the female would turn the right edge of her foot toward the nearest male, and curl it upward with a twisting, rolling motion that brought a small mass of loosely agglutinated sand with it. It seems that sand-grains adhere to the "bubble sac" when they come in contact with it. This twisting action usually continued for about another 10 minutes or so, until the female would

pearance. After remaining in this position for about an hour to an hour and a half, the verge was quickly withdrawn and could be observed as a small white fleshy flap

under the male's shell as he raised and lowered it a few times preparatory to moving away (see Text figure 7). The translucent appearance and bluish color had disappeared, and the verge was the same color as the foot and body of normal adults.

The presence of living *Crepidula onyx* SOWERBY, 1824 on the shell of a female *Mitra idae* (a not unusual occurrence) seemed a deterrent to copulation, although it did not completely prevent it. The male *Mitra* would, while

"feeling" a female's shell with its siphon, quickly withdraw it when coming in contact with the *Crepidula's* shell, evidently being able to sense the difference between the two kinds of shell.

### TERMINATION OF THE EXPERIMENT

The experiments were terminated and the animals still remaining alive were put into alcohol in November 1965, when an unidentified red-colored bacterial growth invaded the filter systems and the entire aquarium, completely covering the floor and sides, and the animals as well. For a time the bacterial growth seemed controllable through the use of medicinal penicillin. It was difficult, however, to regulate the amount of the drug correctly, and in our attempts to strike a balance between barely controlling the obnoxious growth and giving too much penicillin to the animals (several of the *Mitra* died on one or two occasions when the drug was used), we found it impossible to continue.

### EGGS

No eggs were ever laid by any female *Mitra idae* in the aquarium during the course of the experiment, despite the numerous copulatory acts observed during the several months of the experiment.

In the field, observations made by SCUBA divers (Dr. R. C. Fay, personal communication) revealed that *Mitra idae* were laying eggs during July and August, 1965. These eggs were laid on a shell substrate at a depth of 25 feet in the open ocean off southern California, in approximately the same area where the experimental animals had been collected.

A year or two earlier, an unsuccessful attempt had been made to hatch egg capsules of *Mitra idae* in a laboratory at the University of California, Berkeley. At that time, a specimen of *Mitra idae* collected by R. Ames in 30 feet of water at Mission Point, Carmel (Monterey County), was maintained in a jar of sea water in a cold room at 14° C. An airstone was kept in the jar for aeration, but no food was offered at any time during the nearly 3 months the animal was under observation. Approximately one and a half months after capture, the animal deposited a large egg mass on the side of the jar (see Text figure 8). About one month later, one additional egg capsule was deposited. Although at this time motion could be observed in the first-laid capsules, indicating embryonic

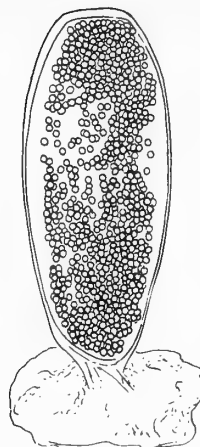


Figure 8

Egg capsule of *Mitra idae*

life in the unhatched veligers, none of the eggs in any of the capsules ever hatched.

### CONCLUSIONS

During the course of eight or nine months, observations were made on the mating behavior of 26 animals of *Mitra idae* MELVILL. Based on these observations, it seems evident that the following conclusions may be made:

1. Males are able to locate females by some sensory means when attracted by a substance emitted by the female in a mucus "bubble sac."
2. The attractant provided by the female is evidently dispersed by means of water currents.
3. Females use their muscular foot and the "bubble sac" in a twisting motion to pick up sand from the substrate, ultimately nearly covering themselves and sometimes the mate as well with loosely agglutinated sand.
4. Observations made during this experiment confirm the fact that *Mitra idae* is a dioecious species, and that fertilization is internal.
5. There seems to be a relationship between the timing of mating action in *Mitra idae* and the exact hour of local high tides even when the animals are a considerable distance from the ocean.

6. *Mitra idae* is able to subsist in a healthy condition without food for a period of at least 8 to 9 months.

7. Either the state of captivity or a lack of food, or both, may have inhibited the production of fertile eggs and the growth of the animals.

### ACKNOWLEDGMENTS

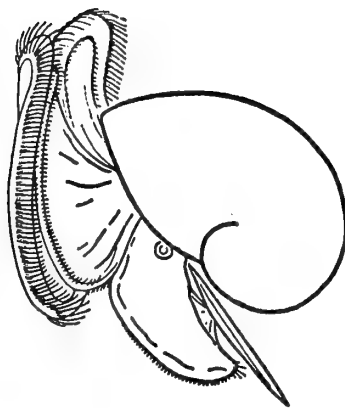
Many persons provided help and encouragement toward the carrying out of this experiment; to all of them I wish to express my gratitude. Crawford Cate was helpful and encouraging in many ways; Dr. Rudolf Stohler assisted in setting up of the original experiment, including the code-marking of the animals, and offered several

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### LITERATURE CITED

STOHLER, RUDOLF

1962. Preliminary report on growth studies in *Olivella biplicata*. The Veliger 4 (3): 150-151; plt. 36 (1 Jan. 1961)



# Structure of the Bivalve Rectum

## I. Morphology

BY

THOMAS C. JEGLA

Department of Biology, Kenyon College, Gambier, Ohio 43022

AND

MICHAEL J. GREENBERG

Department of Biological Sciences, Florida State University, Tallahassee, Florida 32306

(Plates 36 to 40; 1 Text figure)

### INTRODUCTION

THE INTESTINE OF BIVALVES, after leaving the stomach, loops through the visceral mass and is succeeded by the rectum, which courses posteriorly, usually through the pericardium and ventricle, over the posterior adductor, and finally opens into the exhalant current. The rectum is usually attached to the pericardium and ventricle only at its entrance and exit sites in these tissues.

Several investigators, in studies of the digestive tract of bivalve mollusks, have devoted some attention to the morphology and histology of the rectum. These include DAKIN (1909), *Pecten maximus* (LINNAEUS, 1758); GUTHEIL (1912), *Anodonta cellensis* SCHRÖTER, 1779; YONGE (1923), *Mya arenaria* LINNAEUS, 1758; YONGE (1926), *Ostrea edulis* LINNAEUS, 1758; WHITE (1937), *Mytilus edulis* LINNAEUS, 1758; YONGE (1941), seven species of protobranches; and GALTSOFF (1964), *Crassostrea virginica* (GMELIN, 1791). Although primarily interested in the histology and physiology of the heart, MOTLEY (1933) did discuss the trans-ventricular region of the fresh-water bivalve rectum. ARAKAWA (1963, 1965), in his studies on the shape and constitution of molluscan faeces, also looked at the histology of the rectum. Finally, PHILLIS (1966) and NYSTROM (1967), in the course of physiological studies of the *Tapes watlingi* IREDALE, 1958 and *Spisula solidissima* (DILLWYN, 1817) rectums, briefly examined histology. These studies all clearly show that the construction of the rectum varies markedly in the bivalve mollusks.

This report describes the morphology of the rectum of at least one species in each of the orders of the class Bivalvia; 23 families are represented. While the variation is large, familial similarities in rectal construction have been found.

### MATERIALS AND METHODS

The rectum was removed from medium and large individuals, sometimes with the ventricle around it, and fixed in aqueous Bouin's fluid; if the clam was very small, the entire animal was fixed. After the usual histological procedures, the 7–10 micron thick sections were dyed either with Masson's trichrome stain (HUMASON, 1965), Mallory's triple connective tissue stain (GUYER, 1953), or with Ehrlich's hematoxylin with eosin as a counterstain. Masson's, with a very short treatment in the fast green, proved to be most effective for differentiating muscle and connective tissue fibers in molluscan tissues.

### RESULTS

Species of bivalves differ in the cross-sectional morphology of their rectums. Variations in three major characteristics occur:

(1) Bore or shape of the lumen. The lumen is surrounded by a single layer of columnar epithelial cells,

the surface area of which is increased by differential size of the epithelial cells, or by simple folding at various points around the lumen, or by the occurrence of one or more prominent typhlosoles.

(2) Thickness of the wall. A basement membrane, composed of connective tissue fibers that are stained by fast green or aniline blue, lines the basal portions of the epithelial cells. Peripheral to the basement membrane, the tissue of the rectal wall varies considerably in thickness and composition.

(3) Composition and arrangement of tissue elements in the wall. In many species this tissue is thinner than the layer of columnar epithelium and is composed essentially of connective tissue fibers; but in over 50% of the species studied, it is as much as 19 times the thickness of the columnar epithelial layer. In rectums with substantial walls, connective tissue is the basic component; although muscle tissue is usually present, it varies considerably in density and orientation. These characteristics will be discussed in greater detail below.

While the morphology of the rectum remains uniform from intestine to anus in many species, in others there is a progressive change of structure. Therefore, most interspecific comparisons in this paper are made at a standard position, homologous in most of the animals studied: namely, at the level of the auriculo-ventricular valves in the trans-cardiac region of the rectum.

### 1. Bore or shape of the lumen

While the shape of the lumen is variable in bivalve mollusks, generally there is uniformity within a family. Some species have an entirely smooth-bored rectum; all the columnar epithelial cells are of the same size (Text figure 1a; Plate 36, Figure 1 and Plate 38, Figure 5). In the majority of species studied, the smoothness of the bore is interrupted by ridges and furrows, folds, typhlosoles, or some combination of these (see diagrams in Text figure 1). A differential in size of the epithelial cells results in ridges where the cells are largest, and furrows where the cells are smallest (Text figure 1b and Plate 37, Figure 3). Folding of the rectal wall also occurs (Text figure 1c and Plate 36, Figure 2). A typhlosole, as we distinguish it, is a projection of connective tissue, with its covering epithelium, into the lumen (Text figures 1d and 1e); the structure extends for most of the length of the rectum. A typhlosole may be small (Plate 36, Figure 2) or voluminous (Plate 39), single (Plate 39) or multiple (Plate 40, Figure 9). Whatever their condition, typhlosoles considerably increase the surface area of the epithelial lining of the lumen.

The smooth-bored condition may occur among the Protobranchia, Heterodonta and Adapedonta. While it is

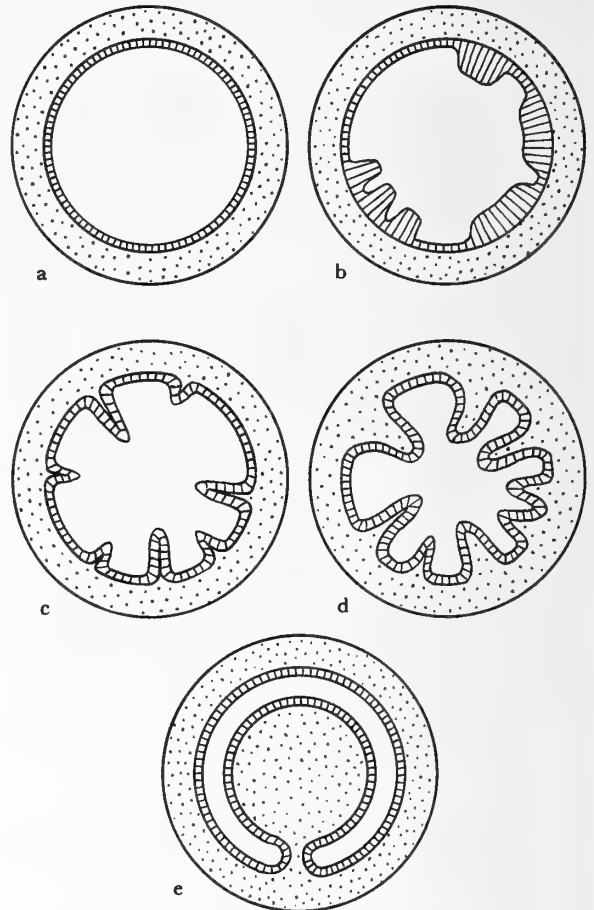


Figure 1

Diagrammatic Cross-Sections of Bivalve Rectums,  
Illustrating Variation in the Bore or Shape of the Lumen  
a - Smooth. Epithelial lining of more or less uniform height.  
b - Variation in height of epithelium producing ridges and furrows.  
c - Folds in the epithelium. d - Small typhlosoles. Peripheral wall tissue, as well as epithelium, is folded into the lumen.  
e - Single, large typhlosole.

frequently found in such small species as *Nucula* and *Donax variabilis* SAY, 1822, there is certainly no relationship between the size of the animal, the diameter of the lumen, or the extent of irregularity of the rectal wall. For example, a smooth-bored rectum occurs in the large species *Mya arenaria* (Plate 38, Figure 5), *Chlamys hindsi*

CARPENTER, 1864 and *Cyrtopleura costata* (LINNAEUS, 1758). The rectum of these animals has a large lumen and an overall diameter of 1.5–2.0 mm, whereas the rectal diameter in the small species is less than 0.3 mm (see *Mactra*, Plate 36, Figure 1). The smoothness of the bore is also unrelated to the thickness of the rectal wall; compare thin-walled *Mactra* (Plate 36, Figure 1) with thick-walled *Mya* (Plate 38, Figure 5). According to YONGE (1923) the rectum of *Mya arenaria* has its columnar epithelium thrown into longitudinal folds, but his illustration (see his figure 24) is of a region very near to the anus. Epithelial folds are commonly found near the anus in rectums where no folds existed in the cardiac region; we have observed this in *Chlamys* and *Macoma*, and GALTISOFF (1964) observed it in *Crassostrea*.

Ridges and furrows along the entire inside perimeter of the rectum were observed in *Acila castrensis* (HINDS, 1843), *Lucina floridana* CONRAD, 1833, *Tridacna maxima* (RÖDING, 1798) and *Cardiomya oldroydi* (DALL in OLDROYD, 1924). The cells vary in height by factors of 1–5, but the absolute size differences vary widely and depend on the species. Often, in combination with differential cell size, folding of the epithelium occurs, and apparently is found only in those species having a thin-walled rectum. We have observed it in *Mytilus edulis* (Plate 37, Figure 3) and *Brachidontes exustus* (LINNAEUS, 1758).

Typhlosoles, alone, invade the rectal lumen in many species in the families Arcidae, Pinnidae, Cardiidae and Unionidae. One or more typhlosoles were observed in the Vulsellidae (VON HAFFNER, 1958), and one large bifurcated typhlosole occurs in the Ostreidae (YONGE, 1926; GALTISOFF, 1964). With respect to lumen volume, the typhlosoles are small in the Cardiidae, but many of them occur on the perimeter of the lumen (Plate 40, Figure 9). The Arcidae and Pinnidae have a typhlosole that is intermediate in size (Plate 39, Figure 8). A single typhlosole reaches the ultimate in relative size in the freshwater family Unionidae where it may reduce the lumen to a slit (Plate 39, Figure 7).

Combinations of ridges and furrows and one or more typhlosoles occur. Among these are *Mytilus californianus* CONRAD, 1837, *Solen sicarius* GOULD, 1850 (Plate 36, Figure 2) and all the species of Veneridae we have studied [*Mercenaria mercenaria* (LINNAEUS, 1758) (Plate 38, Figure 6), *M. campechiensis* (GMELIN, 1791), *Chione cancellata* (LINNAEUS, 1767) and *Macrocallista nimbosa* (LIGHTFOOT, 1786) and *Tapes watlingi* (see PHILLIS, 1966)]. The typhlosoles in these species may be large or small, while, in ridges and furrows, the size of the columnar cells varies from a factor of two in *Chione* and

*Macrocallista* to five or six in *Mercenaria*. The smallest typhlosoles are narrow and have a very thin core of connective tissue, but the largest are very broad-based and have a massive core of connective tissue and some muscle cells.

## 2. Thickness of the wall of the rectum

In five orders of Bivalvia, four or more species were sampled (Table 1). Within the Protobranchia, Anisomyaria and Schizodonta, only a small variation in thickness of the rectal wall was observed. Greater differences occur in the Adapedonta and the large order Heterodonta (Table 2). However, the order notwithstanding, variation is minimal within the families from which we have studied more than one species. The 40 species discussed in this report can be conveniently divided into three types with regard to the thickness of the rectal wall peripheral to the basement membrane of the columnar cells:

- (a) epithelial walls
- (b) thin walls
- (c) thick walls.

(a) **Epithelial walls.** In species with epithelial rectal walls, the columnar cells and their basement membrane account for 90–100% of the wall of the rectum (Plate 36, Figure 1; Plate 37, Figure 4). This condition was found in all four species of Protobranchia, several Heterodonta, and in the lone species of the Anomalodesmata and Septibranchia. Epithelial walls are prevalent among the small species but are not necessarily highly correlated with a small lumen nor with epithelial cell height. A scarcity of tissue external to the basement membrane is observed in the large rectum of *Macoma nasuta* (CONRAD, 1837) (Plate 37, Figure 4) and in the small rectum of *Mactra fragilis* GMELIN, 1791 (Plate 36, Figure 1); the lumen is 70 times larger in *Macoma* than in *Mactra*. Also, the columnar cells are six times taller in *Macoma* than in *Mactra*.

(b) **Thin walls.** In those species with a thin-walled rectum, the average height of the columnar cells and their basement membrane account for 40–80% of the rectal wall; the tissue peripheral to the basement membrane is about as thick as the height of the columnar cells and basement membrane combined (Plate 37, Figure 3). We have found the thin-walled condition in all three families of the Anisomyaria and it is apparently a characteristic of this order. Also half the families studied in both the Heterodonta and Adapedonta have thin walls. Again, thinness of wall and lumen volume are not correlated.

Table 1

Systematic Distribution of the Bivalves used in this Study.  
 Classification after THIELE (1935), ABBOTT (1954) and MORTON & YONGE (1964)

SUBCLASS	ORDER	FAMILY	Genus and species
<b>PROTOBRANCHIA</b>			
		NUCULIDAE	<i>Nucula</i> sp.; <i>Acila castrensis</i> (HINDS, 1843)
		NUCULANIDAE	<i>Nuculana hamata</i> (CARPENTER, 1864); <i>Yoldia limatula</i> (SAY, 1831)
<b>LAMELLIBRANCHIA</b>			
TAXODONTA		ARCIDAE	<i>Noetia ponderosa</i> (SAY, 1822)
ANISOMYARIA		MYTILIDAE	<i>Brachidontes exustus</i> (LINNAEUS, 1758); <i>Mytilus edulis</i> LINNAEUS, 1758; <i>Mytilus californianus</i> CONRAD, 1837
		PINNIDAE	<i>Atrina rigida</i> (LIGHTFOOT, 1786); <i>A. serrata</i> SOWERBY, 1825
		PECTINIDAE	<i>Chlamys hastata hericia</i> (GOULD, 1850); <i>C. hindsii</i> CARPENTER, 1864
HETERODONTA		CORBICULIDAE	<i>Polymesoda caroliniana</i> (BOSC, 1802)
		SPHAERIIDAE	<i>Sphaerium</i> sp.
		LUCINIDAE	<i>Lucina floridana</i> CONRAD, 1833
		CARDIIDAE	<i>Dinocardium robustum</i> (LIGHTFOOT, 1786); <i>Serripes groenlandicus</i> (BRUGUIÈRE, 1789); <i>Clinocardium nuttalli</i> (CONRAD, 1837)
		TRIDACNIDAE	<i>Tridacna maxima</i> (RÖDING, 1798)
		VENERIDAE	<i>Mercenaria mercenaria</i> (LINNAEUS, 1758); <i>M. campechiensis</i> (GMELIN, 1791); <i>Chione cancellata</i> (LINNAEUS, 1767); <i>Macrocallista nimbosa</i> (LIGHTFOOT, 1786)
		MACTRIDAE	<i>Mactra fragilis</i> GMELIN, 1791; <i>Spisula solidissima</i> (DILLWYN, 1817); <i>Rangia cuneata</i> (GRAY, 1837)
		TELLINIDAE	<i>Macoma nasuta</i> (CONRAD, 1837)
		DONACIDAE	<i>Donax variabilis</i> SAY, 1822
		SANGUINOLARIIDAE	<i>Tagelus gibbus</i> (SPENGLER, 1794)
SCHIZODONTA		UNIONIDAE	<i>Actinonaias carinata</i> (BARNES, 1823); <i>Cyclonaias tuberculata</i> (RAFINESQUE, 1820); <i>Quadrula quadrula</i> (RAFINESQUE, 1820); <i>Anodonta cataracta</i> SAY, 1817; <i>Amblyma plicata</i> RAFINESQUE, 1820
ADAPEDONTA		SOLENIDAE	<i>Solen sicarius</i> GOULD, 1850
		HIATELLIDAE	<i>Panope generosa</i> GOULD, 1850
		MYIDAE	<i>Mya arenaria</i> LINNAEUS, 1758
		PHOLADIDAE	<i>Cyrtopleura costata</i> (LINNAEUS, 1758)
ANOMALODESMATA		LYONSIIDAE	<i>Lyonsia striata</i> (MONTAGU, 1815)
<b>SEPTIBRANCHIA</b>			
		CUSPIDARIIDAE	<i>Cardiomya oldroydi</i> (DALL in OLDROYD, 1924)

## Explanation of Plate 36

## Variability in Rectums of Similar Small Size

Figure 1: *Mactra fragilis*. Epithelial wall; smooth bore.

Figure 2: *Solen sicarius*. Thin wall; bore interrupted by epithelial folds. Note small typhlosole in upper left.

C - columnar epithelium

L - lumen

H - heart muscle

W - tissue of the wall

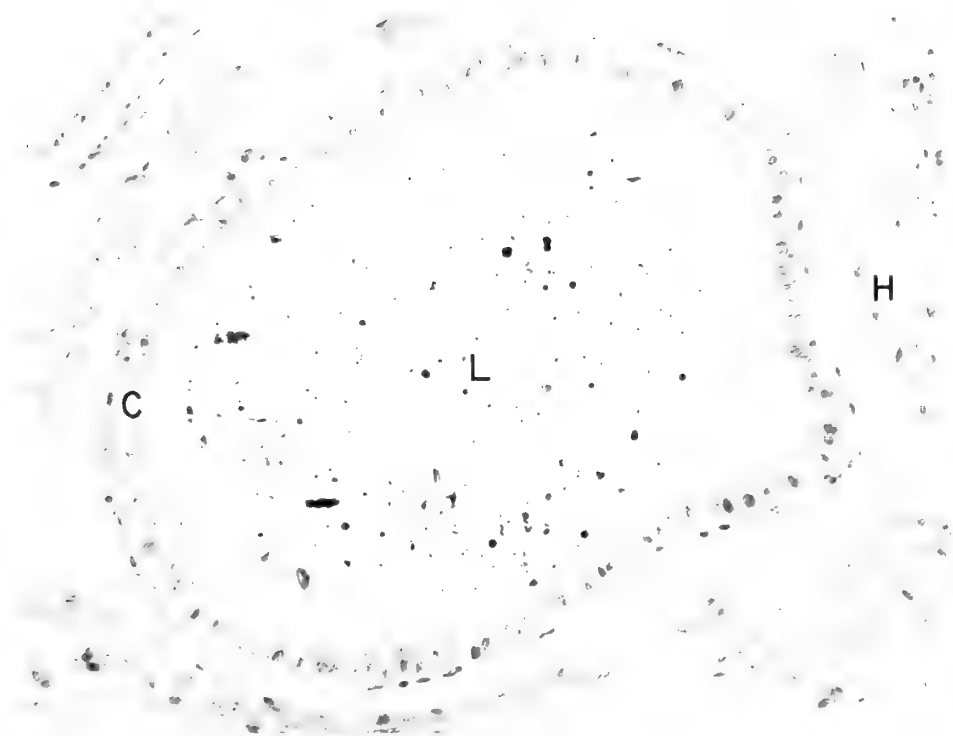


Figure 1

50  $\mu$

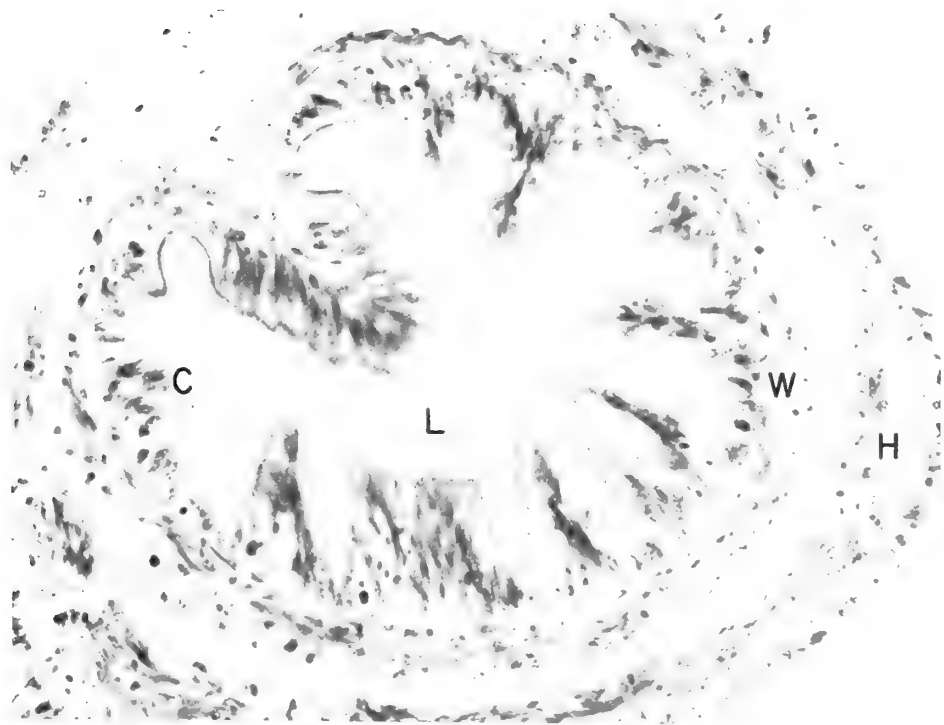


Figure 2

50  $\mu$



Table 2

Thickness of the Rectal Wall and Height of the Columnar Epithelial Cells in Relation to Size of the Species and its Rectum.

(Size of marine species calculated from ABBOTT, 1954)

	Length of animal (mm)	Diameter of the rectum ( $\mu$ )	Height of columnar cells and basement membrane ( $\mu$ )	Thickness of the wall ( $\mu$ )	Ratio epithelium : wall
<i>Nucula</i> sp.	5	225	8.5	8.5	1.0
<i>Acila castrensis</i>	12	509	20.3	20.3	1.0
<i>Nuculana hamata</i>	<12	310	21.0	21.0	1.0
<i>Yoldia limatula</i>	25-62	505	27.2	31.3	0.9
<i>Noetia ponderosa</i>	50-62	1260	78.4	140.9	0.58
<i>Brachidontes exustus</i>	19	840	31.3	52.3	0.59
<i>Mytilus edulis</i>	25-75	1090	56.5	91.0	0.62
<i>Mytilus californianus</i>	50-250	1570	116.0	216.0	0.54
<i>Atrina rigida</i>	125-225	2800	47.0	106.5	0.44
<i>Atrina serrata</i>	125-225	5140	31.3	68.8	0.46
<i>Chlamys hastata hericia</i>	50-70	1390	69.0	128.2	0.54
<i>Chlamys hindsii</i>	50-62	1430	59.5	141.0	0.42
<i>Sphaerium</i> sp.	6-12	192	48.5	57.2	0.85
<i>Lucina floridana</i>	37	356	39.4	58.4	0.68
<i>Dinocardium robustum</i>	75-100	1715	22.0	406.3	0.05
<i>Serripes groenlandicus</i>	50-100	1530	34.5	189.5	0.18
<i>Clinocardium nuttalli</i>	50-150	1270	56.4	258.8	0.22
<i>Tridacna maxima</i> (small)		203	29.7	48.5	0.61
<i>Mercenaria mercenaria</i>	75-125	1400	81.4	284.5	0.29
<i>Mercenaria campechiensis</i>	75-150	1270	40.7	181.5	0.22
<i>Chione cancellata</i>	25-44	390	29.1	65.8	0.33
<i>Macrocallista nimbosa</i>	100-125	2060	56.4	162.5	0.35
<i>Mactra fragilis</i> (small)	50-62	214	14.5	16.0	0.91
<i>Spisula solidissima</i>	100-125	450	47.0	94.5	0.50
<i>Macoma nasuta</i>	50-87	1560	62.6	68.8	0.91
<i>Donax variabilis</i>	12-19	254	12.1	17.1	0.71
<i>Tagelus gibbus</i>	50-87	532	23.5	31.3	0.75
<i>Actinonaias carinata</i>					
very small		1420	28.1	70.5	0.40
very large	127-140	4950	76.2	206.2	0.35
<i>Cyclonaias tuberculata</i>	76	1450	50.0	260.0	0.19
<i>Quadrula quadrula</i>	127-140	2080	47.0	267.0	0.17
<i>Anodonta cataracta</i>	75-100	1820	41.6	253.6	0.16
<i>Amblema plicata</i>	127-140	1804	62.7	191.2	0.33
<i>Solen sicarius</i>	50-100	364	24.4	35.8	0.68
<i>Panope generosa</i>	175-225	1333	78.3	206.4	0.38
<i>Mya arenaria</i>	25-150	1820	42.0	194.0	0.22
<i>Cyrtopleura costata</i>	100-200	1250	32.0	63.6	0.50
<i>Lyonsia striata</i>	12-18	625	15.3	15.3	1.0
<i>Cardiomya oldroydi</i>	6	64	15.0	16.0	0.94

(c) **Thick walls.** A rectum is thick-walled when the average height of the columnar cells and their basement membrane is less than 40% of the thickness of the wall. A thick wall is characteristic of *Mya arenaria* (Plate 38, Figure 5), the Veneridae (Plate 38, Figure 6), Cardiidae (Plate 40, Figure 9), and the Unionidae. Many of the species in these families are large bivalves, but not only the large bivalves have a thick-walled rectum. The thick-walled rectum bears no apparent relationship to gauge or shape of the lumen. Thus, the lumen is large and smooth in *Mya* (Plate 38, Figure 5); large and interrupted by typhlosoles in the Veneridae (Plate 38, Figure 6) and Cardiidae (Plate 40, Figure 9); and nearly obliterated by the huge typhlosole in the Unionidae (Plate 39, Figure 7).

### 3. Composition and arrangement of tissue elements

Conspicuous tissue elements in bivalve rectums are collagen fibers, fibroblast cells, phagocytes, smooth muscle cells, and sometimes vesicular cells. Layering may occur. The nature of the tissue layers, and of their component elements, is closely related to the thickness of the rectal wall external to the basement membrane. Not only is there great similarity within families, but also within some orders.

In those species with epithelial walls, what little outer tissue is present usually consists of a few collagen fibers and perhaps a few fibroblasts and muscle cells.

Many species with a thin-walled rectum are exemplified by the condition observed in the family Pinnidae (Plate 39, Figure 8); the wall of the rectum consists of a dense layer of collagen fibers, fibroblast cells and scattered muscle cells. However, the peripheral portion of the rectal wall of the Pectinidae and *Mytilus californianus* is composed almost entirely of vesicular cells; collagen fibers and muscle cells are densely packed immediately adjacent to the basement membrane but also are scattered through the vesicular layer. In addition the Pectinidae may have visceral organs closely attached to the rectum and they progress with it for some distance through the pericardium

and ventricle. The digestive gland is especially prominent in *Chlamys hindsii*, while in *C. hastata hericia* (GOULD, 1850) both digestive gland and gonad are present. KELLOGG (1890) also found gonad investing most of the length of the rectum of the oyster, *Crassostrea virginica*. *Spisula solidissima*, a heterodont bivalve, has the central half of the wall heavily infiltrated with longitudinal, circular, and oblique muscle fibers and the peripheral half primarily of collagen fibers.

In those species with a thick-walled rectum, the basic component of the wall is connective tissue. In all cases a dense layer of collagen fibers and fibroblasts is found adjacent to the basement membrane; there are also muscle cells in this layer in the Veneridae and Cardiidae (Plate 40). Going peripherally the wall differs, in the various families, primarily with regard to the density and arrangement of muscle. A thin, medial layer of circular and oblique muscle is found in the Unionidae. Venerids have a medial layer of dense longitudinal muscle fibers (Plate 38, Figure 6). In *Mya arenaria* (Plate 38, Figure 5) and the Cardiidae (Plate 40, Figure 9), the dense concentration of circular and oblique muscle occurs in a peripheral layer.

In most species the core tissue of the typhlosole is essentially that of the connective tissue layer adjacent to the basement membrane, but in some species, more than one layer of the wall may extend into the typhlosole (Plate 40, Figure 10). The large unionid typhlosole has a dense filling of collagen fibers, fibroblasts and muscle cells which fold in from the medial layer. In addition, numerous large blood sinuses course throughout the fibrous layer (Plate 39, Figure 7).

## DISCUSSION

The distinguishing morphological features – shape of the lumen, thickness of the rectal wall, occurrence of the various tissue elements, and orientation of muscle fibers – which characterize the rectums of bivalve mollusks

## Explanation of Plate 37

### Variability in Rectal Structure

Figure 3: *Mytilus edulis*. Characteristic shape of anisomyarian rectum. Thin wall; ridges and furrows. The two large ventral ridges are the remnant of the intestinal typhlosolar folds.

Figure 4: *Macoma nasuta*. Large rectum with epithelial wall and smooth bore; compare with Figure 1, Plate 36. Note folds on ventral side.

C – columnar epithelium  
H – heart muscle

L – lumen  
W – tissue of the wall



Figure 3

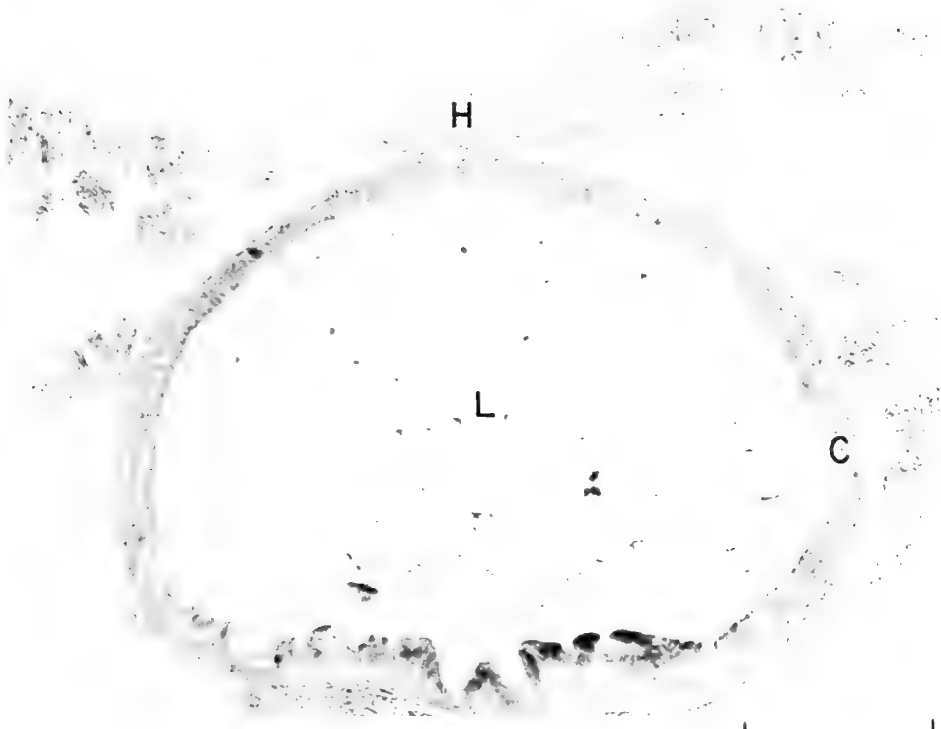


Figure 4



have been summarized, by families, in Table 3. These features are consistent enough to enable one to distinguish between families. Some similarities also appear at the ordinal level; these are discussed below:

Among the Protobranchia (Nuculidae and Nuculanidae) the structure of the rectum is only slightly variable. It is smooth bored and has an epithelial type wall. An illustration of *Nucula nucleus* (LINNAEUS, 1758) in PELSENEER (1906) and descriptions of *Malletia* by YONGE (1941) indicate that these species do not differ materially in pattern from those we have observed.

Rectums in the order Anisomyaria [*Pecten maximus* (DAKIN, 1909); *Lima inflata* LAMARCK, 1819 (VON STUDNITZ, 1931); *Ostrea edulis* (YONGE, 1926); *Mytilus edulis* (WHITE, 1937); *Vulsella* (VON HAFFNER, 1958); *Crassostrea virginica* (GALTSOFF, 1964); and species listed in Table 2] are basically similar. All have a relatively thin wall; the muscle fibers are few in number, and are usually not organized into layers or bundles. Also, in *Mytilus californianus* and the Pectinidae visceral mass tissue (vesicular storage cells, gonad, or digestive gland) extends, with the rectum into the trans-ventricular region. This has also been observed in *Crassostrea virginica* by KELLOGG (1890) and therefore it may be a general morphological characteristic of the order. On the other hand, this extension of the viscera may be a seasonal phenomenon associated with expansion of the gonad in the breeding season.

The continuous change in rectal structure, from intestine to anus, is conspicuous in the Anisomyaria. One of these changes is the reduction and decrease in height of the well-developed intestinal typhlosole folds to two broad ridges with a mid-ventral furrow (Plate 37, Figure 3). The large, bifurcated *Atrina* rectal typhlosole (Plate 39, Figure 8) is clearly homologous to the same structure in *Mytilus* intestine. Finally, in most species, the rectum is flattened to a crescentic shape.

We have observed five genera in the order Schizodonta, all in the family Unionidae. There are no significant differences among the species in structure of the rectum, and the rectum is strikingly different from that of any other species in any other order of bivalves that has been examined. The one unmistakable feature common to all unionids is the very large typhlosole which reduces the lumen to a slit, and which persists for the entire length of the rectum. Also characteristic is the extensive blood sinus system permeating the connective tissue core of the typhlosole. Previous studies have included the genus *Anodonta* (VOGT & YUNG, 1888, and GUTHEIL, 1912) and the genera *Tritogonia*, *Lasmagonia*, *Elliptio*, *Fusconaia*, *Lamprosilis* and *Megaloniais* (MOTLEY, 1933).

While species in the large order Heterodonta exhibit a variety of rectal structures, we have observed considerable intra-family similarity. Furthermore, reports in the literature support this. Outstanding characteristics of the order as a whole do exist. Large animals, especially in some families, show a heavy muscular development, usually circular, in a robust rectal wall. The occurrence of many small typhlosoles is another common feature (see Table 3).

Although the number of species available for comparison is small, the degree of variation in rectal form in the order Adapedonta seems to approach that of the heterodonts. Thus, while *Mya* and *Cyrtopleura* are without significant sculpturing of the columnar epithelium both differences of columnar cell size and typhlosoles occur in *Solen* and *Panope*. Again, the wall is thick and heavily muscular in *Mya* but relatively thin in *Cyrtopleura* and *Solen*. In all, the rectum is essentially circular in transverse section.

We have, thus, found only two orders of Bivalvia whose rectal structure is characteristic of that, and no other, order: Anisomyaria and Schizodonta. According to COX (1960), the modern Arcacea and the superfamilies of the Anisomyaria arose from a common cyrtodontid ancestral stock in the early Ordovician. However, based on the morphology of the gills and stomach and on the fossil record there is some question as to whether the Mytilacea share this ancestry or arose from the Modioloipsidae, another early Ordovician fossil family; this evidence is also summarized by Cox. The unique form of the anisomyarian rectum, and its occurrence, although modified, in an arcid confirms the idea of common ancestry. A morphological feature which occurs in such highly evolved animals as the Ostreacea, Pinnacea, and Mytilacea, must be highly conservative. Since we find no evidence of its existence in the Protobranchia or Heterodonta (although it would be interesting to examine the primitive Astartidae) we assume that the anisomyarian rectum arose after the divergence of the cyrtodont stock from that of the above subclasses.

STASEK (1963) has produced a phylogenetic scheme correlating his studies on the ctenidium-palp association, the stomach types of PURCHON (1963), and the fossil record. The distribution of the anisomyarian rectum is identical to that of the stomach type. Namely, all the anisomyarians except the Pectinacea (and the Anomiacea which we haven't studied) have stomach type 3, which is also found nowhere else. The Pectinacea have a type 4 stomach and also, in this group, the usual rectal structure cannot be recognized. The ctenidium-palp association

Table 3

Summary of the Structure of the Rectum in some Families of Bivalvia

FAMILY	Shape of Lumen	Ratio epithelium: wall thickness	Tissue Elements
NUCULIDAE	smooth or small difference in cc size	0.9-1.0	none or ct
NUCULANIDAE	nearly smooth	0.9-1.0	none or ct
ARCIDAE	large typhlosole	0.58	mostly ct, cm; some vc
MYTILIDAE	ridges and furrows, folding of wall or a typhlosole	0.54-0.62	mostly ct; a few cm, lm; may have layer of vc
PINNIDAE	1 large typhlosole	0.45	mostly ct; a few lm, om
PECTINIDAE	smooth or small typhlosoles	0.42-0.54	some ct, cm, lm; visceral mass tissues
SPHAERIIDAE	essentially smooth	0.85	ct
CORBICULIDAE	essentially smooth	0.85	ct; a few cm
LUCINIDAE	small difference in cc	0.65	dense layer of ct
CARDIIDAE	ridges and furrows, and many typhlo- soles	0.05-0.22	dense layer of ct, a few cm, om; dense, thick layer cm, lm
TRIDACNIDAE	small difference in cc	0.61	mostly ct; a few cm
VENERIDAE	ridges and furrows, and many typhlo- soles	0.22-0.35	dense layer of ct, some cm, lm; dense layer ct, lm; layer ct, some lm
MACTRIDAE	smooth or small difference in cc	0.50-0.91	some ct or layer of cm, om, lm and dense layer ct, some lm
TELLINIDAE	smooth to a small difference in cc	0.91	mostly ct
DONACIDAE	smooth	0.71	ct
SANGUINOLARIIDAE	smooth	0.75	ct, a few cm
UNIONIDAE	1 large typhlosole	0.16-0.35	dense layer ct; layer of cm, om; layer ct with cm
SOLENIDAE	ridges and furrows and 1 typhlosole	0.68	dense ct, some cm
HIATELLIDAE	ridges and furrows and several typhlo- soles	0.38	ct, some cm
MYIDAE	essentially smooth	0.22	layer of ct; dense layer cm, some ct, om
PHOLADIDAE	smooth	0.50	ct, some cm
LYONSIDAE	smooth	1.0	none
CUSPIDARIIDAE	smooth to a small difference in cc	0.94	ct

cc - height of columnar cells  
cm - circular muscle cells  
ct - connective tissue

lm - longitudinal muscle cells  
om - oblique muscle cells  
vc - vesicular cells

## Explanation of Plate 38

## Variability in Thick-Walled Rectums of Similar Large Size

Figure 5: *Mya arenaria*. Smooth bore. Note dense circular muscle layer in periphery of the wall.

Figure 6: *Mercenaria mercenaria*. Many small typhlosoles as well as ridges and furrows. This is a characteristic of venerid rectums. Note thick layer of longitudinal muscle, and paucity of circular muscle.

C - columnar epithelium      H - heart muscle  
CM - circular muscle      L - lumen  
CT - connective tissue      LM - longitudinal muscle  
W - tissue of the wall

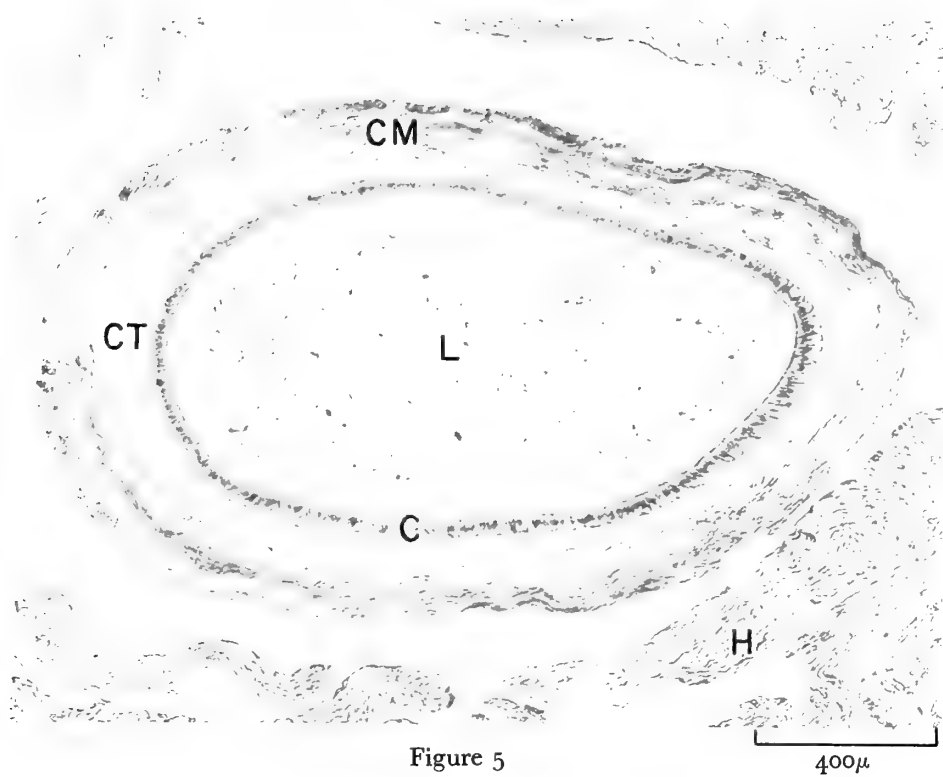


Figure 5

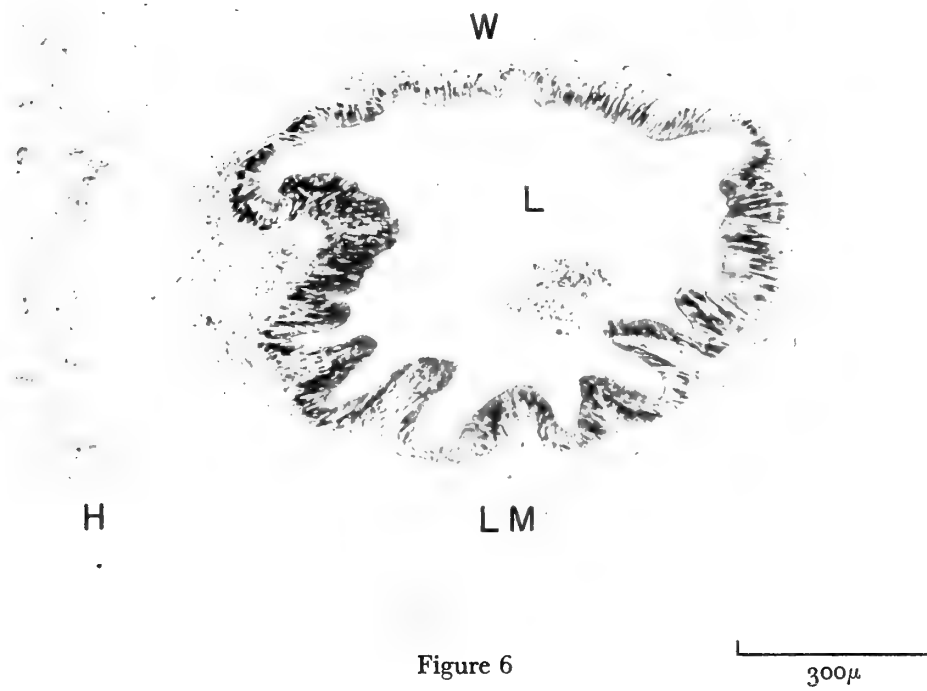


Figure 6



(STASEK, 1963) distribution is dissimilar; apparently the most primitive Category I arose in the Cambrian and divergence began very early.

Other morphological features of the Anisomyaria and Arcidae are well known (e. g. MORTON & YONGE, 1964). In addition, one of us (M. J. G., unpublished) has observed that, in the Mytilidae, Ostreidae, Pectinidae, and Pteriidae, the auricles are glandular and communicate with each other posteriorly and ventral to the ventricle. This condition was not found in the Pinnidae.

The uniform rectal structure of the Unionidae, taken together with their freshwater habitat suggests that this rectum might be an adaptation to the hyposmotic environment. In particular, the presence of sinuses suggests that the typhlosole might function in osmoregulation. PICKEN (1937) and PORTS (1954) found that blood was filtered through the heart to the pericardial cavity. Possibly filtration also occurs into the rectum facilitated by the blood sinuses in the typhlosole. The typhlosole epithelium, in contrast to the remaining rectal lining, stains intensely (Plate 39, Figure 7). This characteristic also suggests some unique function of this region. However, the rectums of other fresh- and brackish water bivalves have been studied: *Polymesoda caroliniana* (Bosc, 1802) and *Sphaerium* sp., both from the superfamily Sphaeriacea, and *Rangia cuneata* (GRAY, 1837), a mactrid. In all of these species, the rectum was thin-walled, relatively smooth, and lacked, altogether, a typhlosole. Thus, while the unionid rectum might have evolved as an environmental adaptation, this has happened only once. Although *Rangia cuneata* is subjected to considerable osmotic stress, the rectum resembles closely those of *Spisula solidissima* and *Mactra fragilis*, the other marine members of the family studied.

The important, mandatory function of the rectum is preparation and propulsion of faecal material. Therefore the shape and composition of the faeces are useful indicators of the functional morphology of the rectum. In a recent consideration of molluscan faeces, KORNICKER (1962) has outlined the structure and distribution of five major kinds of bivalve faecal pellets and has suggested evolutionary trends connecting them. His generalizations are borne out by ARAKAWA's later description of the faeces from a number of species (1963; 1965).

Protobranch faeces are always pellets which are broken-off pieces of sculptured rods. In the Anisomyaria, 60% of the species studied had either sculptured or ribbonlike faecal pellets. The ribbonlike faeces are also sculptured and have ventrally curved edges. They are, of course, casts of the unique flattened rectums previously described as characteristic of this order. Heterodont faeces are usually

either unsculptured or shapeless, and oval pellets appear only in this order. KORNICKER points out that the sediments in sculptured faeces are segregated by particle size in different portions of the faecal rod, whereas the composition of unsculptured, shapeless, and oval pellets is uniform. He concludes that sculptured faeces with segregated sediments are primitive, while unsculptured, oval, and shapeless faeces, with their uniform composition, are derived forms.

Sculpturing and particle distribution are largely dependent upon the mechanism by which faeces are propelled through the rectum. If propulsion is by means of ciliary tracts, with little muscle involvement, then there can be no gross mechanical activity accompanying the passage of the faecal rod. Consequently, the distribution of sediments determined by the ciliary sorting systems of the stomach and gut will be undisturbed; similarly, the surface sculpturing of the rod will be preserved. On the other hand, a muscular rectum would probably obliterate surface sculpturing, and also thoroughly mix the sediment. If the faeces are of appropriate consistency, and if the peristaltic contractions are sufficiently powerful, the gut contents will be molded into a string of oval pellets. The distribution of muscle among bivalve rectums is well correlated with the distribution of sculptured and unsculptured faeces. Muscular rectums are found mainly among the Heterodonta. Protobranch and anisomyarian rectums have, characteristically, thin walls with little muscle.

What is the functional significance of the interfamily differences in rectal structure? A reasonable supposition is that they should be related in some way to feeding and digestive mechanisms. The possibility is best examined in the Heterodonta, since the rectum in this order is mostly notable for its variability from family to family. Thus, one might expect to find some relationship between rectal structure and stomach-type (PURCHON, 1963), gill-palp association (STASEK, 1963), habitat, or diet. None was observed. Thus, while subtle species specific differences in rectal physiology occur, and while they must be related to structural differences, probably at the submicroscopic level (GREENBERG, 1966), there are no such relationships at the level of gross histology. The rectum in Bivalvia is, therefore, a non-adaptive structure which has undergone little change since the divergence of the families.

## ACKNOWLEDGMENTS

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## Explanation of Plate 39

### Rectums with Voluminous Typhlosoles

Figure 7: *Actinonaias carinata*. Characteristic schizodont rectum. Note large vascular channels, lined by endothelium, in the typhlosole.

Figure 8: *Atrina rigida*. Note modified anisomyarian rectum; compare with Figure 3, Plate 37.

C - columnar epithelium	L - lumen
CH - vascular channels	T - typhlosole
H - heart muscle	W - tissue of the wall

## Explanation of Plate 40

### Solid Typhlosoles in the Rectum of *Dinocardium robustum*

Figure 9: Low magnification photograph. Note thick wall with extensive, dense musculature in the periphery of the wall, and many moderately large, solid typhlosoles.

Figure 10: Details of structure of typhlosole. Note penetration of connective tissue fibers and muscle cells into the typhlosole, and lack of vascular channels; compare with Plate 39, Figure 7.

C - columnar epithelium	L - lumen
CTF - connective tissue fibers	M - muscle cell
H - heart muscle	T - typhlosole
W - tissue of the wall	

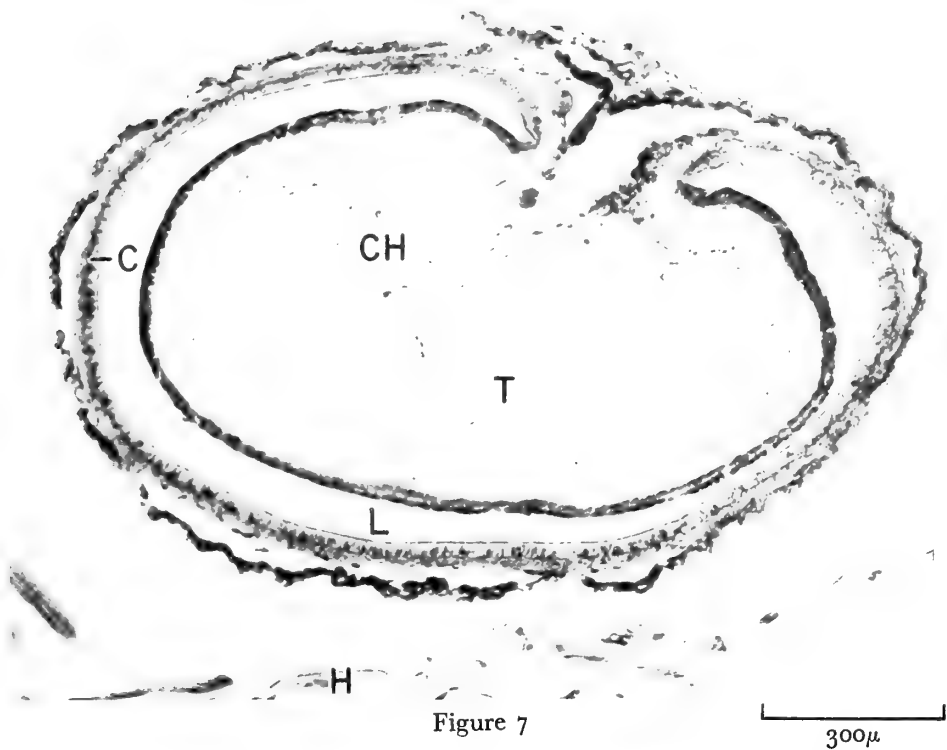


Figure 7

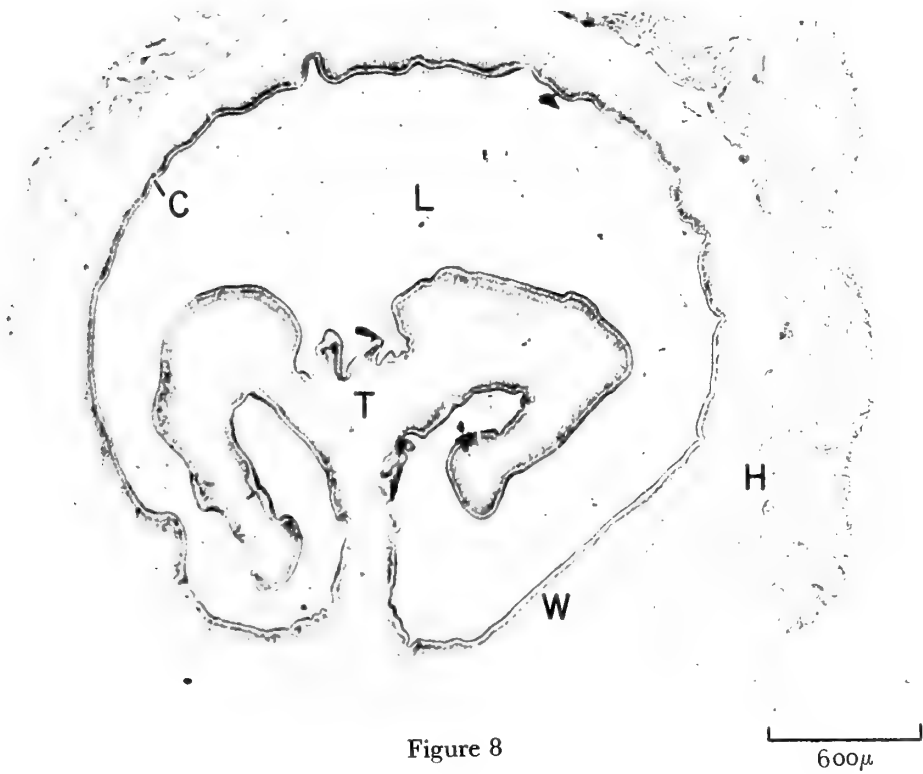


Figure 8



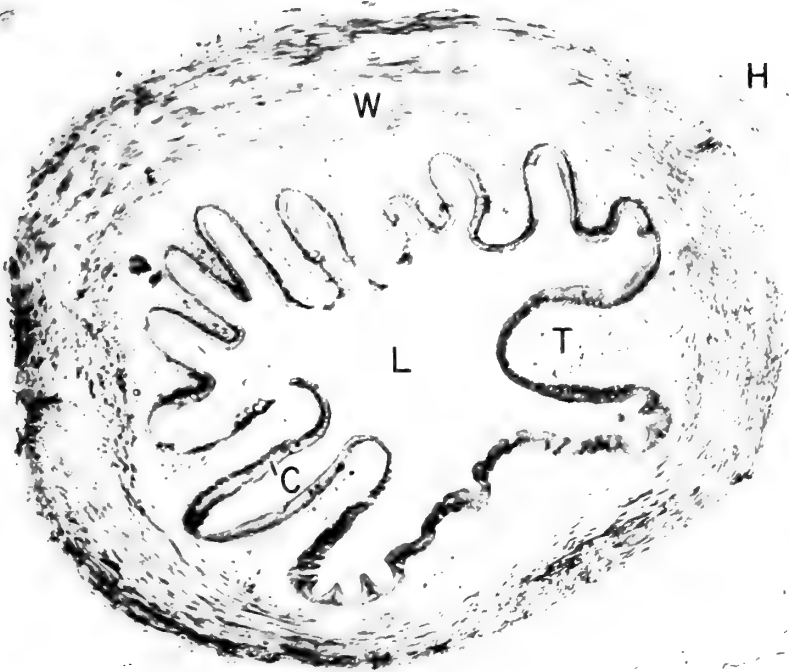


Figure 9

500 $\mu$

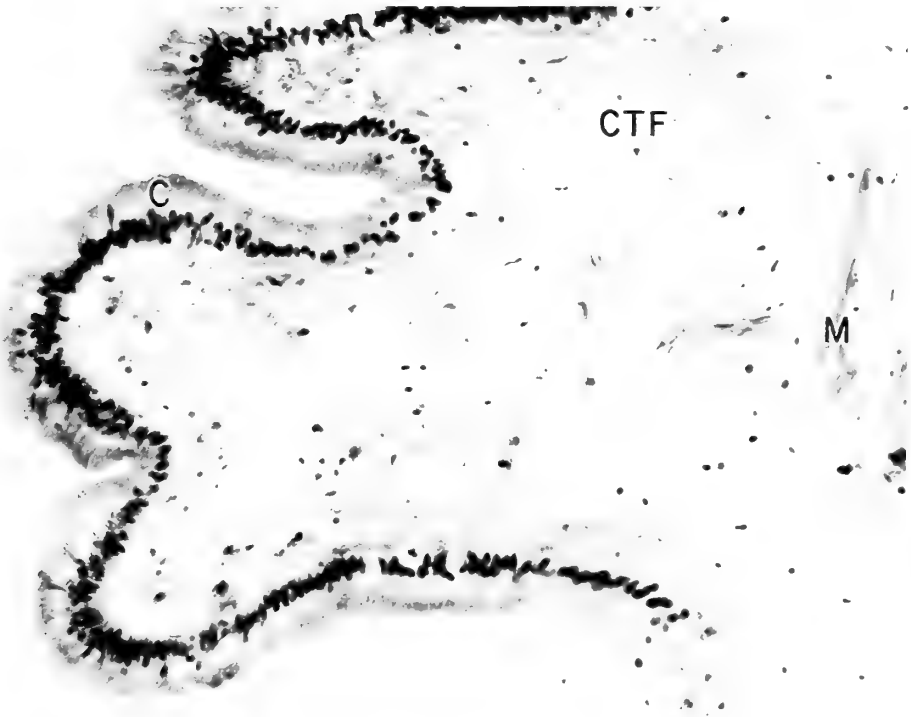


Figure 10

50  $\mu$



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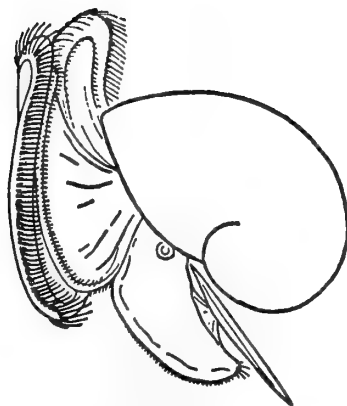
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# The Generic Classification of Cowries

BY

FRANZ ALFRED SCHILDER

University of Halle, German Democratic Republic

IN A PREVIOUS PAPER (SCHILDER, 1966) I have published a survey of the superfamilies, families, subfamilies, and tribus (infra families) of the "true" cowries (Cypraeidae) and of the closely allied groups of mollusca, the "false" cowries: Triviidae, Pediculariidae, and Ovulidae. In the present paper this survey will be expanded to a list of all genera and subgenera belonging to these higher taxa, with their type species and synonyms.

A similar list has been published about a quarter of a century ago (SCHILDER, 1941: 65-68), but since that time many new generic names have been established. The main morphological differences of allied taxa have been discussed two years earlier (SCHILDER, 1939).

In the present list the names of SUPERFAMILIES, FAMILIES, Subfamilies and (Tribus) have been distinguished by type styles, indicating the taxonomic category; *generic* and (*subgeneric*) names have been enumerated as coordinated names in a taxonomic order thought to be a phylogenetic order also; but to the (*subgenera*) the *genus* to which they should be united has been added in square brackets [ ]. Synonyms have been listed in chronological order.

The nine subfamilies have been distinguished by the digits 1 to 9; a second digit indicates the tribus; these bold face figures facilitate the spotting of names enumerated in the alphabetical index.

In the systematic list the following symbols have been used:

- † the dagger designates extinct taxa
- || names invalid by homonymy
- / (preceding the name) not valid, as established by an invalid author or in an invalid way, and never adopted in a valid way
- / (separating the name and the author) wrong interpretation by adopting a wrong type species
- = objective synonym by identity of the type species
- [=] subjective synonym, as the different type species now are supposed to belong to the same subgenus or indivisible genus
- (...) misspelled generic names, invalid authors, and names of tribus have been put in parentheses

[...] opinions of the author of the present paper have been put in square brackets

The type species of genera and subgenera have been distinguished as follows:

- M monotypical
- TT type species by absolute tautonymy
- OD type species by original designation
- SD type species by subsequent designation with the author added
- ex. example only, not valid type species

The meaning of other abbreviations is as follows:

- > < type species cited between these symbols
- err. errore, name misspelled by mistake
- em. name emended by a later author on purpose
- pro name replacing another name, mostly on account of homonymy
- nud. nomen nudum (invalid)
- obl. nomen oblitum: not cited for past 50 years (invalid)
- syn. used as a synonym only (invalid)
- MS manuscript name only (invalid)

The two papers of JOUSSEAUME both published in 1884 should be distinguished: 1884a (Naturaliste, p. 414) undoubtedly is prior to 1884b (Bull. Soc. Zool. France 9: 81), as 1884a has been published February 15 1884, while 1884b has been read only before the Society on February 12 and therefore has been printed much later. Nevertheless, concerning 4 differences in spelling of new names (*Cribraria*, *Mauxiena*, *Trona*, *Zonaria*) I agree with all later writers in adopting the names of 1884b as valid, since 1884a is a popular excerpt only which contains many errors in spelling of species names.

## SYSTEMATIC LIST

TRIVIACEA TROSCHER, 1863

TRIVIIDAE TROSCHER, 1863

1 Eratoinae SCHILDER, 1927

11 †(Johnstrupiini) SCHILDER, 1939

†*Johnstrupia* RAVN, 1933

> M †*Johnstrupia* †*faxensis* RAVN, 1933 <

- 12 †*Eratodium* KOROBKOV, 1955  
> M *Erato* (?) †*medius* ISAEVA, 1933 <  
[possibly no genus of Triviacea at all]
- 13 †(Eratotrivini) SCHILDER, 1936  
†*Eratotrivia* SACCO, 1894  
> OD *Cypraea* ||†*crenata* DESHAYES, 1835 =  
†*Eratotrivia* †*crenularis* SCHILDER, 1927 <
- (Eratoini) SCHILDER, 1927  
†*Proterato* SCHILDER, 1927  
> OD *Erato* †*neozelandica* SUTER, 1917 <  
*Sulcerato* FINLAY, 1930 [*Proterato* subgenus]  
> OD *Erato* †*illota* TATE, 1890 <  
[=] *Lachryma* (HUMPHREY, MS, SOWERBY, 1837 syn.) COTTON & GODFREY, 1932  
> OD *Erato* (*trifasciata* HUMPHREY, MS =) *Erato lachryma* SOWERBY, 1832 <  
*Eratoena* IREDALE, 1935 [*Proterato* subgenus]  
> OD *Ovulum corrugatum* HINDS, 1844 <  
*Cypraeerato* SCHILDER, 1932 [*Proterato* subgenus]  
> OD *Erato bimaculata* TATE, 1878 <  
[=] *Lachryma* IREDALE, 1931 nud.  
> M *Lachryma bisinventa* IREDALE, 1931 <  
†*Archierato* SCHILDER, 1932  
> OD *Erato* (*Erato*) †*pyrulata* TATE, 1890 <  
*Eratopsis* HÖRNES & AUINGER, 1880 [*Erato* subgenus]  
> M *Eratopsis* †*barrandei* HÖRNES & AUINGER, 1880 <  
*Erato* RISSO, 1826  
> M *Marginella* †*cypraeola* BROCCHI, 1814  
*Hespererato* SCHILDER, 1932  
> OD *Ovulum vitellinum* HINDS, 1844 <
- 2 Triviinae TROSCHER, 1863
- 21 (Triviellini) SCHILDER, 1939  
†*Willungia* POWELL, 1938  
> OD †*Willungia* †*tasmanica* POWELL, 1938 <  
†*Semitrivia* COSSMANN, 1903  
> OD *Trivia* †*terugata* TATE, 1890 <  
*Fossatrivia* IREDALE, 1931  
> M *Trivia caelatura* HEDLEY, 1918 <  
†*Nototrivia* SCHILDER, 1932  
> M, SD SCHILDER 1932 Foss. Cat.: *Cypraea* (*Trivia*) †*avellanoides* MCCOY, 1867 <  
*Triviella* JOUSSEAUME, 1884a  
> SD JOUSSEAUME, 1884b: *Cypraea* ||*oniscus* LAMARCK, 1810 = *Cypraea aperta* SWAINSON, 1822 <  
†*Prototrivia* SCHILDER, 1941  
> M *Cypraea* (*Trivia*) †*twetherellii* EDWARDS, 1854 <
- 22 (Triviini) TROSCHER, 1863  
*Trivia* BRODERIP, 1837  
> SD GRAY, 1847: *Cypraea europaea* MONTAGU, 1808 = *Cypraea monacha* COSTA, 1778 <  
(em.) *Trivea* SWAINSON, 1840  
[=] || *Coccinella* (SOWERBY, 1823 syn.) HERRMANNSEN, 1846  
> OD *Cypraea arctica* MONTAGU, 1803 <  
*Sulcotrivia* SCHILDER, 1933 [*Trivia* subgenus]  
> OD *Cypraea* †*dimidiata* BRONN, 1831 <
- 23 (Pusulini) SCHILDER, 1936  
*Pseudotrivia* SCHILDER, 1936  
> OD *Trivia sibogae* SCHEPMAN, 1909 <  
*Ellatrivia* IREDALE, 1931 [*Niveria* subgenus]  
> OD *Triviella merces* IREDALE, 1924 <  
*Cleotrivia* IREDALE, 1930 [*Niveria* subgenus]  
> OD *Cypraea pilula* KIENER, 1843 <  
*Niveria* JOUSSEAUME, 1884a  
> M, SD JOUSSEAUME, 1884b: *Cypraea* ||*nivca* GRAY, MS = SOWERBY, 1832 = *Trivia nix* SCHILDER, 1922 <  
*Trivirostra* JOUSSEAUME, 1884a, 1884b  
> SD ROBERTS, 1885: *Cypraea oryza* LAMARCK, 1810 <  
*Dolichupis* IREDALE, 1930 [*Pusula* subgenus]  
> OD *Cypraea producta* GASKOIN, 1836 <  
[=] *Trivellona* IREDALE, 1931  
> M *Trivellona excelsa* IREDALE, 1931 <  
*Pusula* JOUSSEAUME, 1884a, 1884b  
> SD ROBERTS, 1885: *Cypraea radians* LAMARCK, 1810 <  
(err.) *Pustula* ROBERTS, 1885  
(err.) *Vusula* COSSMANN, 1896
- 30 PEDICULARIIDAE ADAMS & ADAMS, 1854  
†*Semicypraea* SCHILDER, 1936  
> OD *Cypraea koninckii* ROUAULT, 1850 <  
†*Cypraeogemmula* VREDENBURG, 1920  
> M *Trivia* ||†*scabriuscula* KOENEN, 1890 = *Cypraea* †*liliputana* SCHILDER, 1922 <  
*Pediculariona* IREDALE, 1935 [*Pedicularia* subgenus]  
> M *Pedicularia stylasteris* HEDLEY, 1903 <  
? [=] *Dentiora* PEASE, 1862  
> M *Dentiora rubida* PEASE, 1862 = [possibly]  
*Pedicularia pacifica* PEASE, 1865 <  
*Pediculariella* THIELE, 1925 [*Pedicularia* subgenus]  
> OD *Pedicularia californica* NEWCOMB, 1864 <  
*Pedicularia* SWAINSON, 1840  
> M *Pedicularia sicula* SWAINSON, 1840 <

- =|| *Thyreus* PHILIPPI, 1844  
 > M *Thyreus paradoxus* PHILIPPI, 1844 =  
*Pedicularia sicula* SWAINSON, 1840 <

## CYPRAEACEA GRAY, 1824

## CYPRAEIDAE GRAY, 1824

- 4 Bernayinae SCHILDER, 1927
- 41 (†Archicypraeini) SCHILDER, 1927  
 [=] (†Mandolinini) SCHILDER, 1936  
 †*Palaeocypraea* SCHILDER, 1928  
 > OD †*Cypraeacites* †*spiratus* SCHLOTHEIM, 1820 <  
 [=] || †*Palaeocypraea* SAYN, 1932 [nov. genus]!  
 > SD SCHILDER, 1936: *Cypraea* (†*Palaeocypraea*) || †*antiqua* SAYN, 1932 = †*Palaeocypraea* †*primigenia* SCHILDER, 1936 <  
 (=†*Porcellanites* (WALLER, 1747; ARGENVILLE, 1757; SCHRÖTER, 1782, 1783), SCHLOTHEIM, 1813 nud.  
 > M †*Porcellanites* †*seelandicus* SCHLOTHEIM, 1813 nud., which is = †*Cypraeacites* †*spiratus* SCHLOTHEIM, 1820 according to BRONN, 1848 <  
 †*Pustulariopsis* SCHILDER, 1941 [†*Palaeocypraea* subgenus]  
 > OD *Cypraea* †*pustulifera* PARONA, 1909 <  
 †*Archicypraea* SCHILDER, 1926  
 > OD *Cypraea* †*lioyi* BAYAN, 1870 <  
 †*Mandolina* JOUSSEAUME, 1884a  
 > M, SD JOUSSEAUME, 1884b: *Cypraea* || †*gibbosa* BORSON, 1820 = *Cypraea* (†*Mandolina*) || †*gibbosa* BORSON, 1820 var. *pergibba* SACCO, 1894 <
- 42 (Bernayini) SCHILDER, 1927  
 [=] (Cypraeorbini) SCHILDER, 1927  
 [=] (Zoilini) IREDALE, 1935  
*Protocypraea* SCHILDER, 1927 [*Bernayia* subgenus]  
 > OD †*Eocypraea* †*orbignyana* VREDENBURG, 1920 <  
*Bernayia* JOUSSEAUME, 1884a  
 > SD JOUSSEAUME, 1884b: *Cypraea* †*media* DESHAYES, 1835 < (em.) *Bernayia* COSSMANN, 1889  
 †*Barycypraea* SCHILDER, 1927  
 > OD *Cypraea* (*Aricia*) †*caputviperae* MARTIN, 1899 <  
 †*Afrocypraea* SCHILDER, 1932 [possibly no Cypraeidae at all]  
 > OD *Cypraea* †*chubbi* RENNIE, 1930 <  
*Zoila* JOUSSEAUME, 1884a  
 > SD JOUSSEAUME, 1884b: *Cypraea* *scottii* BRODERIP, 1831 = *Cypraea* *friendii* GRAY, 1831 <

- †*Gigantocypraea* SCHILDER, 1927 [*Zoila* subgenus]  
 > OD *Cypraea* †*gigas* MCCOY, 1867 <  
 †*Cypraeorbis* CONRAD, 1865  
 > M *Cypraea* †*sphaeroides* CONRAD, 1847 <  
*Akleistostoma* GARDNER, 1948 [†*Siphocypraea* subgenus]  
 > OD *Cypraea* †*carolinensis* CONRAD, 1841 <  
 [=] *Muracypraea* WOODRING, 1957  
 > OD *Cypraea* *mus* LINNAEUS, 1758 <  
 ?[=] †*Cypraeactaeon* WHITE, 1887  
 > M †*Cypraeactaeon* †*pennai* [em.] WHITE, 1887 [figs. 1 and 2 only, according to SCHILDER, 1927] <  
 †*Siphocypraea* HEILPRIN, 1887  
 > M †*Siphocypraea* †*problematica* HEILPRIN, 1887 <
- 43 (†*Gisortii*) SCHILDER, 1927  
 †*Megalocypraea* SCHILDER, 1927 [†*Gisortia* subgenus]  
 > OD †*Gisortia* (†*Megalocypraea*) †*ovumstruthionis* SCHILDER, 1927 <  
 [=] †*Pseudogisortia* SCHILDER, 1941  
 > OD †*Gisortia* †*benedicti* VREDENBURG, (1920) 1927 <  
 †*Gisortia* JOUSSEAUME, 1884a  
 > SD JOUSSEAUME, 1884b: *Ovula* †*gisortiana* PASSY, 1859 <  
 †*Vicetia* FABIANI, 1905  
 > M *Ovula* †*hantkeni* LEFÈVRE, 1878 <
- 5 Cypraeinae GRAY, 1824
- 51 (Cypraeini) GRAY, 1824  
 [=] (Porcellanini) ROBERTS, 1870  
 [=] (Talpariini) SCHILDER, 1936  
 [=] (Mauritiini) STEADMAN & COTTON, 1946
- †*Miolyncina* SCHILDER, 1932  
 > OD *Cypraea* †*subovum* ORBIGNY, 1852 <  
*Trona* JOUSSEAUME, 1884b  
 > OD *Cypraea* *stercoraria* LINNAEUS, 1758 <  
 (err.) *Etrona* JOUSSEAUME, 1884a  
 ex. *Cypraea* *stercoraria* LINNAEUS, 1758  
 [=] || †*Basterotia* JOUSSEAUME, 1884b  
 > OD *Cypraea* †*leporina* LAMARCK, 1810 <  
 (err.) †*Basterotia* JOUSSEAUME, 1884a  
 ex. *Cypraea* †*leporina* LAMARCK, 1810  
 = †*Cavicypraea* COSSMANN, 1896  
 pro || †*Basterotia* JOUSSEAUME, 1884b
- Macrocypraea* SCHILDER, 1930  
 > OD *Cypraea* *exanthema* LINNAEUS, 1767 =

*Cypraea zebra* LINNAEUS, 1758 <

(= *Cypraea*/LAMARCK, 1801 ex.  
*Cypraea exanthema* LINNAEUS,  
1767)

(= *Cypraea*/JOUSSEAUME, 1884b  
SD JOUSSEAUME, 1884b: *Cypraea*  
*exanthema* LINNAEUS, 1767)

(= *Erythraea* (BARRELLIER, 1714;  
SOWERBY, 1839 syn.) MÖRCH,  
1877; /SCHILDER, 1924)

pro || *Tigris* TROSCHER, 1863  
therefore

> SD SCHILDER, 1924: *Cypraea exanthema* LINNAEUS, 1767 =  
*Cypraea zebra* LINNAEUS, 1758 not valid <

*Leporicypraea* IREDALE, 1930 [*Mauri-*  
*tia* subgenus]

> OD *Cypraea mappa* LINNAEUS, 1758 <

(= *Cypraea*/LAMARCK, 1799 ex.  
*Cypraea mappa* LINNAEUS, 1758)

(= *Cypraea*/COSSMANN, 1903: SD  
COSSMANN, 1903: *Cypraea map-*  
*pa* LINNAEUS, 1758)

*Arabica* JOUSSEAUME, 1884a [*Mauri-*  
*tia* subgenus]

> TT, SD JOUSSEAUME, 1884b: *Cypraea arabica* LINNAEUS,  
1758 <

(err.) *Arabia* JOUSSEAUME, 1886

(= *Cypraea*/SWAINSON, 1840, ex.,  
SD SCHILDER, 1924: *Cypraea ara-*  
*bica* LINNAEUS, 1758)

*Mauritia* TROSCHER, 1863

> SD COSSMANN, 1903: *Cypraea mauritiana* LINNAEUS,  
1758 <

= *Maurina* JOUSSEAUME, 1884a

> M *Cypraea mauritiana* LINNAEUS, 1758 <

= *Mauxiena* JOUSSEAUME, 1884b  
[err. for *Maurina*?]

> M, OD *Cypraea mauritiana* LINNAEUS, 1758 <

= *Etronsa* JOUSSEAUME, 1886 [err.  
for *Etrona*?]

> M *Cypraea mauritiana* LINNAEUS, 1758 <

(= *Cypraea*/COSSMANN, 1889, SD  
COSSMANN, 1889: *Cypraea mau-*  
*ritiana* LINNAEUS, 1758)

(= *Peribolus* (ADANSON, 1757)

BLAINVILLE, 1824 (obl.) M Potan  
ADANSON, 1757 = *Cypraea mau-*  
*ritiana* LINNAEUS, 1758 juvenis  
[adopted as generic name by KU-  
RODA, 1960 and AZUMA, 1960])

*Talparia* TROSCHER, 1863

> M, SD SCHILDER, 1924: *Cypraea talpa* LINNAEUS, 1758 <  
(= *Cypraea*/MELVILL, 1888, SD  
MELVILL, 1888: *Cypraea talpa*  
LINNAEUS, 1758)

*Cypraea* LINNAEUS (1740), 1758

> SD MONTFORT, 1810: *Cypraea tigris* LINNAEUS, 1758 <

(err.) *Cyproea* SERRES, 1822

(err.) *Cipraea* CHIAJE, 1827

(cm.) *Cypraea* COSTA, 1776, ABEL,  
1787, MONTFORT, 1810

(cm.) || *Cypria* JEFFREYS, 1867

[=] *Cypriarius* DUMÉRIL, 1806 pro  
*Cypraea* LINNAEUS, 1758

(cm.) *Cypraearius* FROEY, 1806

= || *Tigris* TROSCHER, 1863 [preoccu-  
pied by (LINNAEUS, 1735) OKEN,  
1816

> TT, SD COSSMANN, 1903: *Cypraea tigris* LINNAEUS, 1758 <

= *Erythraea* (BARRELLIER, 1714) SO-  
WERBY, 1839 syn.) MÖRCH, 1877  
pro *Tigris* TROSCHER, 1863 [nec  
KLEIN, 1753]

(err.) (*Aerythraea* ADANSON, 1757)

= *Vulgusella* JOUSSEAUME, 1884a

> SD JOUSSEAUME, 1884b: *Cypraea tigris* LINNAEUS, 1758 <

(err.) *Vulpicella* COSSMANN, 1889,  
1896, OPPENHEIM, 1894 [correc-  
ted by COSSMANN, 1906]

[=] *Pantherinaria* SACCO, 1894

> OD *Cypraea pantherina* SOLANDER, 1786 <

*Lyncina* TROSCHER, 1863

> SD TRYON, 1883: *Cypraea lynx* LINNAEUS, 1758 <

[=] || *Porcellana* (RUMPHIUS, 1705)

LINCK, 1783, ROBERTS, 1870

> SD JOUSSEAUME, 1884b: *Cypraea argus* LINNAEUS, 1758 <

[=] *Ponda* JOUSSEAUME, 1884a

> SD JOUSSEAUME, 1884b: *Cypraea achatina* (SOLAN-  
DER) PERRY 1811 = *Cypraea ventriculus* LAMARCK,  
1810 <

([=] *Lyncina*/SCHILDER, 1924)

> SD SCHILDER, 1924: *Cypraea carneola* LINNAEUS, 1758 <

[=] *Prolyncina* SCHILDER, 1927

> OD *Cypraea reevei* SOWERBY, 1832 <

[=] *Callistocypraea* SCHILDER, 1927

> OD *Cypraea aurantium* (MARTYN, 1784 =) GMELIN,  
1791 <

[=] *Arestorides* IREDALE, 1930

> OD *Cypraea argus* LINNAEUS, 1758 <

(err.) *Aristorides* CATE, 1967

[=] *Mystaponda* IREDALE, 1930

> OD *Cypraea vitellus* LINNAEUS, 1758 <

- 52 (Luriini) SCHILDER, 1932  
 †*Jousseaumea* SACCO, 1894 [em. by  
 SCHILDER, 1927 and ICZN Opin.  
 673, 1963]  
 > OD *Cypraea* †*sublyncoides* ORBIGNY, 1852 [= *Cypraea*  
 †*diluviana* GRAY, 1824] <  
 (=†*Jousseaumia* SACCO, 1894, original  
 spelling)  
 †*Fossacypraea* SCHILDER, 1939 [*Jous-  
 seaumea* subgenus]  
 > OD *Cypraea* †*hieroglyphica* SCHILDER, 1923 <  
*Chelycypraea* SCHILDER, 1927  
 > OD *Cypraea* †*testudinaria* LINNAEUS, 1758 <  
*Luria* JOUSSEAUME, 1884a  
 > SD JOUSSEAUME, 1884b: *Cypraea lurida* LINNAEUS, 1758 <  
 [=] *Tessellata* JOUSSEAUME, 1884a  
 [em. by JOUSSEAUME, 1884b]  
 > TT, M *Cypraea tessellata* SWAINSON, 1822 <  
 [=] *Basilitrona* IREDALE, 1930  
 > OD *Cypraea isabella* LINNAEUS, 1758 <
- 6 Erroneinae SCHILDER, 1927
- 61 (Zonariini) SCHILDER, 1932  
 †*Prozonarina* SCHILDER, 1941 [†*Zona-  
 rina* subgenus]  
 > OD *Cypraea* †*brocchii* DESHAYES, 1844 <  
 †*Zonarina* SACCO, 1894  
 > OD *Cypraea* †*pinguis* SACCO, 1894 [nec GRATELOUP,  
 1845] = †*longouulina* SACCO, 1894 <  
*Schilderia* TOMLIN, 1930  
 pro|| *Globulina* CERULLI, 1911; OD  
*Cypraea* †*utriculata* LAMARCK,  
 1810  
 = || *Globulina* CERULLI, 1911  
 > M *Globulina* †*infernoi* CERULLI, 1911 = *Cypraea* †*utriculata*  
 LAMARCK, 1810 juvenis <  
*Zonaria* JOUSSEAUME, 1884b  
 > OD *Cypraea zonata* (CHEMNITZ, 1788) LAMARCK,  
 1810 [= *Cypraea zonaria* GMELIN, 1791] <  
 (err.) *Zonatia* JOUSSEAUME, 1884a  
 ex. *Cypraea zonata* (CHEMNITZ, 1788) [= *zonaria*  
 GMELIN, 1791]  
 [=] *Pseudozonaria* SCHILDER, 1927  
 > OD *Cypraea arabicula* LAMARCK, 1810 <  
*Neobernaya* SCHILDER, 1927 [*Zonaria*  
 subgenus]  
 > OD *Cypraea spadicea* SWAINSON, 1823 <
- 62 (Cypraeovulini) SCHILDER, 1927  
 [=] (Umbiliini) SCHILDER, 1932  
 †*Notoluponia* SCHILDER, 1935  
 > OD †*Notoluponia* †*murraviana* †*elegantior* SCHILDER, 1935 <
- Luponia* BRODERIP, 1837 [*Cypraeovula*  
 subgenus]  
 > M *Cypraea algoensis* GRAY, 1825 <  
 (err.) *Lupina* BRONN, 1853  
 (err.) *Luponaria* WEINKAUFF, 1881  
 (err.) *Luponica* WEINKAUFF, 1881  
 (err.) *Luperia* OPPENHEIM, 1901  
 [=] *Gaskoinia* ROBERTS, 1870  
 > M *Cypraea edentula* GRAY, 1825 <  
*Cypraeovula* GRAY, 1824  
 > M, SD GRAY, 1828: *Cypraea capensis* GRAY, 1828 <  
 (err.) *Cypraeovula* FLEMING, 1828  
 (err.) *Cyprovula* GRAY, 1828, 1840,  
 1847  
 (em.) *Cypraeovulum* SOWERBY, 1842  
 (em.) *Cypraeova* SWAINSON, 1840  
 (em.) *Cypraeovum* SCHAUFUSS, 1869  
*Guttacypraea* IREDALE, 1935 [*Notocypr-  
 raea* subgenus]  
 > OD *Cypraea pulicaria* REEVE, 1846 <  
*Notocypraea* SCHILDER, 1927  
 > OD *Cypraea piperita* GRAY, 1825 <  
 [=] *Thelxinovum* IREDALE, 1931  
 > OD *Thelxinovum mölleri* IREDALE, 1931 [= *Noto-  
 cypraea emblema* IREDALE, 1931] <  
 †*Rhynchocypraea* COSSMANN, 1898  
 [*Umbilia* subgenus]  
 > OD *Cypraea* (*Luponia*) †*leptorhyncha* MCCOY, 1877 <  
*Umbilia* JOUSSEAUME, 1884a  
 > M, SD JOUSSEAUME, 1884b: *Cypraea* || *umbilicata*  
 SOWERBY, 1825 = *Cypraea hesitata* IREDALE, 1916 <  
 [=] †*Rhynchocypraea* /COSSMANN,  
 1903  
 > SD COSSMANN, 1903: †*Rhynchocypraea* †*loxorhyncha*  
 [sic] /COSSMANN, 1903 fig. [= *Umbilia* †*maccoyi*  
 SCHILDER, 1932 nec *Cypraea* †*toxorhyncha* TATE, 1890] <  
 †*Palliocypraea* COSSMANN, 1906 [*Um-  
 bilia* subgenus]  
 > OD *Cypraea* (*Aricia*) †*gastroplax* MCCOY, 1875 <
- 63 (Erroneini) SCHILDER, 1927  
 [=] (Adustini) STEADMAN & COTTON, 1946  
*Gratiadusta* IREDALE, 1930 [*Erronea*  
 subgenus]  
 > OD *Cypraea pyriformis* GRAY, 1824 <  
 = *Ipserronea* IREDALE, 1935  
 > OD *Ipserronea problematica* IREDALE, 1935 = *Cypraea*  
*pyriformis* GRAY, 1824 juvenis [according to  
 IREDALE, 1939] <  
 [=] *Ficadusta* HABE & KOSUGE, 1966  
 > OD *Cypraea pulchella* SWAINSON, 1823 <

- Adusta* JOUSSEAUME, 1884a [*Erronea* subgenus]  
 > TT, SD JOUSSEAUME, 1884b: *Cypraea adusta* (CHEMNITZ, 1788) = *Cypraea adusta* LAMARCK, 1810 <  
 [=] *Solvadusta* IREDALE, 1935  
 > OD *Gratiadusta vaticina* IREDALE, 1931 <  
*Erronea* TROSCHER, 1863  
 > M, SD JOUSSEAUME, 1884b: *Cypraea erronea* LINNAEUS, 1758 <  
 [=] *Palangerosa* IREDALE, 1930  
 > OD *Cypraea cylindrica* BORN, 1778 <  
*Melicerona* IREDALE, 1930 [*Erronea* subgenus]  
 > OD *Cypraea listeri* GRAY, 1824 <  
*Notadusta* SCHILDER, 1935  
 > OD *Notadusta victoriana* SCHILDER, 1935 <  
*Palmadusta* IREDALE, 1930  
 > OD *Cypraea clandestina* LINNAEUS, 1767 <  
 [=] *Evenaria* IREDALE, 1930  
 > OD *Cypraea asellus* LINNAEUS, 1758 <  
 (err.) *Evanaria* STEADMAN & COTTON, 1943 [always]  
*Purpuradusta* SCHILDER, 1939 [November] [*Palmadusta* subgenus]  
 > OD *Cypraea fimbriata* GMELIN, 1791 <  
 [=] *Opponaria* IREDALE, 1939 [December]  
 > OD *Cypraea minoridens* MELVILL, 1901 ["minoridens series"] <  
 [=] *Cupinota* IREDALE, 1939 [December]  
 > OD *Cypraea macula* ANGAS, 1867 <  
*Blasicrura* IREDALE, 1930 [*Bistolida* subgenus]  
 > OD *Cypraea rhinoceros* SOUVERBIE, 1865 <  
 [=] *Eclogavena* IREDALE, 1930  
 > OD *Cypraea coxeni* COX, 1873 <  
 [=] *Talostolida* IREDALE, 1931  
 > OD *Cypraea teres* GMELIN, 1791 <  
*Bistolida* COSSMANN, 1920  
 pro || *Stolida* JOUSSEAUME, 1884b  
 = || *Stolida* JOUSSEAUME, 1884a  
 > TT, SD JOUSSEAUME, 1884b: *Cypraea stolida* LINNAEUS, 1758 <  
 = *Derstolida* IREDALE, 1935  
 > OD *Derstolida fluctuans* IREDALE, 1935 [= *Cypraea stolida* LINNAEUS, 1758] <  
*Ovatipsa* IREDALE, 1931  
 > OD *Cypraea chinensis* GMELIN, 1791 <

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- Cribrarula* STRAND, 1929  
 pro || *Cribraria* JOUSSEAUME, 1884b  
 (err.) *Cribraria* JOUSSEAUME, 1884a  
 > TT *Cypraea cribraria* [err. pro *cribraria*] LINNAEUS, 1758 <  
 = || *Cribraria* JOUSSEAUME, 1884b  
 > TT, OD *Cypraea cribraria* LINNAEUS, 1758 <  
 = *Nivigena* IREDALE, 1930  
 > M, OD *Nivigena melwardi* IREDALE, 1930 [= variety of *Cypraea cribraria* LINNAEUS, 1758] <  
*Erosariinae* SCHILDER, 1924  
 (*Pustulariini*) SCHILDER, 1932  
 [=] (*Cypracacitini*) SCHILDER, 1930  
 [=] (*Austrocypracini*) IREDALE, 1935  
 [=] (*Conocypracini*) SCHILDER, 1936  
*Annepona* IREDALE, 1935 [*Pustularia* subgenus]  
 > OD *Cypraea* || *annulata* GRAY, 1828 = *Pustularia maria* SCHILDER, 1927 <  
 (= *Epona*/ (WEINKAUFF, 1881) IREDALE, 1939)  
 > SD WEINKAUFF, 1881: *Cypraea* || *annulata* GRAY, 1828 according to IREDALE, 1939 to be proved [in WEINKAUFF, 1881 no type species; || *annulata* GRAY, 1828 is the first named species only] <  
*Pustularia* SWAINSON, 1840  
 > M *Cypraea cicercula* LINNAEUS, 1758 <  
 (err.) *Postularia* COCCONI, 1873  
 = *Epona* ADAMS & ADAMS, 1854  
 > SD MELVILL, 1888: *Cypraea cicercula* GMELIN, 1791 = LINNAEUS, 1758 <  
 (err.) *Eponia* ROSSITER, 1882  
 (err.) || *Globularia* SOWERBY, 1842, ex. *Cypraea globulus* LINNAEUS, 1758  
*Ipsa* JOUSSEAUME, 1884a, b [*Pustularia* subgenus]  
 > M *Cypraea childreni* [em.] GRAY, 1825 <  
 † *Austrocypraea* COSSMANN, 1903  
 > OD *Cypraea* (*Luponia*) † *contusa* MCCOY, 1877 <  
 † *Proadusta* SACCO, 1894  
 > OD *Cypraea* † *splendens* / SACCO, 1894 [nec GRATELOUP, 1827] = † *denticulina* SACCO, 1894 <  
 [=] † *Conocypraea* OPPENHEIM, 1901  
 > SD SCHILDER, 1924: *Cypraea* † *persona* OPPENHEIM, 1901 <  
 [=] † *Cypraeacites* (SCHLOTHEIM, 1820: not available according to IRZN art. 56b) SCHILDER, 1931  
 > SD SCHILDER, 1924: † *Cypraeacites* † *inflatus* / SCHLOTHEIM, 1820 = *Cypraea* † *meyeri* BÖTTGER, 1883 <

- (err.) †*Cyprecites* ORBIGNY, 1850  
 (err.) †*Cypraeites* BÖTTGER, 1883  
*Propustularia* SCHILDER, 1927 [†*Proadusta* subgenus]  
 > OD *Cypraea surinamensis* PERRY, 1811 pro *Cypraea bicallosa* GRAY, 1831 <
- 72 (Erosariini) SCHILDER, 1924  
 [=] (Nariini) SCHILDER, 1932  
 [=] (Staphylacini) IREDALE, 1935  
*Monetaria* TROSCHER, 1863  
 > SD ROBERTS, 1885: *Cypraea moneta* LINNAEUS, 1758 <  
 ==//*Thoracium* (RUMPHIUS, 1705) LINNAEUS, 1758 syn. [comprises *Monetaria* and *Ornamentaria*]  
 ==//*Aricia* BRODERIP, 1837  
 > SD FISCHER, 1884: *Cypraea moneta* LINNAEUS, 1758 <  
 (err.) *Aria* DESHAYES, 1865  
 (err.) *Mercatoria* MELVILL, 1888  
*Ornamentaria* SCHILDER & SCHILDER in SCHILDER, 1936 [*Monetaria* subgenus]  
 > OD *Cypraea annulus* LINNAEUS, 1758 <  
 ==// *Aricia*/MELVILL, 1888  
 > SD MELVILL, 1888: *Cypraea annulus* LINNAEUS, 1758 <  
*Naria* BRODERIP, 1837  
 > M *Cypraea irrorata* GRAY, 1828 <  
*Paulonaria* IREDALE, 1930 [*Erosaria* subgenus]  
 > OD *Cypraea beekii* GASKOIN, 1836 <  
*Erosaria* TROSCHER, 1863  
 > SD JOUSSEAUME, 1884b: *Cypraea erosa* LINNAEUS, 1758 <  
 [=]//*Ocellaria* WEINKAUFF, 1881  
 > SD SCHILDER, 1927: *Cypraea spurca* LINNAEUS, 1758 <  
 [=] *Ravitronea* IREDALE, 1930  
 > OD *Cypraea caputserpentis* LINNAEUS, 1758 <  
 [=] *Perisserosa* IREDALE, 1930  
 > OD *Perisserosa brocktoni* IREDALE, 1930 = *Cypraea guttata* GMELIN, 1791 <  
 [=] *Albacyprea* STEADMAN & COTTON, 1946  
 > OD *Cypraea eburnea* BARNES, 1824 <  
*Staphylaea* JOUSSEAUME, 1884a  
 > TT, SD JOUSSEAUME, 1884b: *Cypraea staphylaea* LINNAEUS, 1758 <  
 [=] *Purperosa* IREDALE, 1935  
 > OD *Purperosa facifer* IREDALE, 1935 [= *Cypraea limacina* LAMARCK, 1810] <  
 [=] *Eustaphylaea* STEADMAN & COTTON, 1946  
 > OD *Cypraea semiplota* MIGHELS, 1845 <
- Nucleolaria* OYAMA, 1959  
 > pro *Nuclearia* JOUSSEAUME, 1884b, OD *Cypraea nucleus* LINNAEUS, 1758 <  
 ==//*Nuclearia* JOUSSEAUME, 1884a  
 > SD JOUSSEAUME, 1884b: *Cypraea nucleus* LINNAEUS, 1758 <
- OVULIDAE FLEMING, 1828  
 == [em.] AMPHIPERATIDAE ADAMS & ADAMS, 1854
- 8 Eocypraeinae SCHILDER, 1924
- 81 (Eocypraeini) SCHILDER, 1924  
 [=] (Sulcocypreaeini) SCHILDER, 1932  
 [=] (Pseudocypreaeini) STEADMAN & COTTON, 1943  
 †*Eocypraea* COSSMANN, 1903  
 > OD *Cypraea tinflata* LAMARCK, 1802 <  
 †*Oxycyprea* SCHILDER, 1927 [†*Eocypraea* subgenus]  
 > OD *Ovula* †*delphinoides* COSSMANN, 1886 <  
 †*Apiocyprea* SCHILDER, 1927  
 > OD *Cypraea* †*michaudiana* GRATELOUP, 1847 <  
 †*Eschatocyprea* SCHILDER, 1966 [†*Apiocyprea* subgenus]  
 > OD †*Eschatocyprea* †*balcombica* SCHILDER, 1966 <  
*Pseudocyprea* SCHILDER, 1927  
 > OD *Cypraea adamsonii* SOWERBY, 1832 <  
 †*Sulcocyprea* CONRAD, 1865  
 > M *Cypraea* †*lintea* CONRAD, 1847 <  
 †*Sphaerocyprea* SCHILDER, 1927  
 > OD *Cypraea* †*bowerbankii* SOWERBY, 1850 <  
 [=] †*Marginocyprea* INGRAM, 1947  
 > OD †*Marginocyprea* †*paraguana* INGRAM, 1947  
 [= †*Sphaerocyprea* †*wegeneri* SCHILDER, 1939] <
- 82 (Cyproglobinini) SCHILDER, 1932  
 [=] (Jenneriini) THIELE, 1929  
 †*Cyproglobina* GREGORIO, 1880  
 > M, SD COSSMANN, 1903: *Cypraea* (†*Cyproglobina*) †*parvulorbis* GREGORIO, 1880 <  
 (em.) †*Cypraeoglobina* COSSMANN, 1903  
 †*Luponovula* SACCO, 1894 [†*Cyproglobina* subgenus]  
 > OD *Cypraea* †*proserpinac* BAYAN, 1870 [= *Cypraea* †*rugosa* BRODERIP, 1827] <  
 †*Cypraeopsis* SCHILDER, 1936 [†*Cyproglobina* subgenus]  
 > OD †*Cypraeopsis* †*vanderwerkeri* SCHILDER, 1936 <  
 †*Eotrivia* SCHILDER, 1924 [†*Cypropteria* subgenus]  
 > OD *Cypraea* (*Trivia*) †*bouryi* COSSMANN, 1889 <

- †*Cypropterina* GREGORIO, 1880  
 > M *Cypraea* (†*Cypropterina*) †*ceciliae* GREGORIO, 1880 <  
 †*Cypraeotrivina* VREDENBURG, 1920  
 [†*Cypropterina* subgenus]  
 > OD *Cypraea* †*duclosiana* BASTEROT, 1825 <  
*Jenneria* JOUSSEAUME, 1884a [†*Cyp-*  
*ropterina* subgenus]  
 > SD JOUSSEAUME, 1884b: *Cypraea pustulata* LAMARCK,  
 1810 [= *pustulata* SOLANDER, 1786] <  
 (= *Pustularia*/MELVILL, 1888)  
 > SD MELVILL, 1888: *Cypraea pustulata* LAMARCK, 1810 <  
 †*Transovula* GREGORIO, 1880  
 > M, SD COSSMANN, 1903: †*Transovula* †*schefferi*  
 GREGORIO, 1880 <
- 83 (†*Cypraediini*) SCHILDER, 1927  
 †*Cypraedia* SWAINSON, 1840  
 > M †*Cypraedia* †*cancellata* SWAINSON, 1840 [= *Cypraea*  
 †*elegans* SOWERBY, 1823] <  
 (err.) †*Cypraedia* SOWERBY, 1842  
 (err.) †*Cypraedia* TATE, 1892  
 = †*Cypraoides* AGASSIZ, 1846 (pro  
 †*Cypraedia* SWAINSON, 1840)  
 [=] †*Protocypraedia* SCHILDER, 1927  
 > OD *Cypraea* (†*Cypraedia*) †*conigera* MARTIN, 1914 <  
 †*Eucypraedia* SCHILDER, 1939 [†*Cyp-*  
*raedia* subgenus]  
 > OD *Cypraea* †*sulcosa* LAMARCK, 1802 <  
 †*Eovolva* SCHILDER, 1932  
 > OD *Amphiperas* †*nigeriensis* NEWTON, 1922 <
- 9 Ovulinae FLEMING, 1828
- 91 (Ovulini) FLEMING, 1828  
 = *Amphiperasini* ADAMS & ADAMS, 1854  
 = (em.) *Amphiperatini* WINCKWORTH,  
 1929
- Prionovolva* IREDALE, 1930  
 > OD *Ovulum breve* SOWERBY, 1828 <  
*Diminovula* IREDALE, 1930 [*Primovula*  
 subgenus]  
 > OD *Diminovula verepunctata* IREDALE, 1930 <  
 [=] *Margovula* IREDALE, 1935  
 > OD *Ovulum pyriforme* SOWERBY, 1828 <  
*Pseudosimnia* SCHILDER, 1927 [*Prim-*  
*ovula* subgenus]  
 > OD *Bulla carnea* POIRET, 1789 <  
 (err.) *Pseudosinarica* ARRECGROS,  
 1958
- Primovula* THIELE, 1925  
 > OD *Amphiperas beckeri* SOWERBY, 1900 <
- [=] *Dentivolva* HABE, 1961  
 > OD *Ovulum dorsuosum* HINDS, 1844 <  
*Prosimnia* SCHILDER, 1927 [*Primovula*  
 subgenus]  
 > OD *Ovula semperi* WEINKAUFF, 1881 [= *Ovulum*  
*coarctatum* ADAMS & REEVE, 1848] <  
*Procalpurnus* THIELE, 1929 [*Calpur-*  
*nus* subgenus]  
 > OD *Ovula lactea* LAMARCK, 1810 <  
*Calpurnus* MONTFORT, 1810  
 > OD *Bulla verrucosa* LINNAEUS, 1758 <  
 = *Cypraella* SWAINSON, 1840  
 > M *Bulla verrucosa* LINNAEUS, 1758 <  
 (err.) *Cypraela* SOWERBY, 1842  
*Ovula* BRUGUIÈRE, 1789  
 > SD LAMARCK, 1801: *Ovula oviformis* LAMARCK, 1801  
 [= *Bulla ovum* LINNAEUS, 1758] <  
 (em.) *Ovulus* MONTFORT, 1810  
 (em.) *Ovulum* SOWERBY, 1828  
 (em.) *Ovularia* LINK, 1830  
 (err.) *Anula* GRIFFITH, 1834  
 =/ *Semiporcellana* COSTA, 1776 (obl.,  
 ADAMS & ADAMS, 1854, syn.)  
 > SD SCHILDER, this paper: *Bulla ovum* LINNAEUS, 1758 <  
 =/ *Licium* (HUMPHREY, 1797)  
 ADAMS & ADAMS, 1854, syn.  
 > SD SCHILDER, this paper: *Bulla ovum* LINNAEUS, 1758 <  
 = *Amphiperas* (GRONOW, 1781, not  
 valid according to ICZN opinion  
 261) HERRMANNSEN, 1846; A-  
 DAMS & ADAMS, 1854  
 > SD HERRMANNSEN, 1846: *Bulla ovum* LINNAEUS, 1758 <  
 (err.) *Amphiceras* GRAY, 1847  
 [=] *Particum* IREDALE, 1935  
 > OD *Ovula costellata* LAMARCK, 1810 <
- 92 (Simniini) SCHILDER, 1927  
 [=] (Volvini) SCHILDER, 1932  
*Simnia* RISSO, 1826  
 > SD GRAY, 1847: *Simnia nicaeensis* RISSO, 1826 <  
 (err.) *Scymnia* RISSO, 1826 (partim)  
 (err.) || *Simia* LEACH, 1847  
 [=] †*Calpurna* FLEMING, 1828  
 > M *Ovula fleathesi* J. SOWERBY, 1825 <  
 [=] *Neosimnia* FISCHER, 1884  
 > OD *Bulla spelta* LINNAEUS, 1758 <  
*Cyphoma* RÖDING, 1798  
 > M *Bulla gibbosa* LINNAEUS, 1758 <  
 (err.) || *Cyphonia* GRAY, 1847  
 = *Ultimus* MONTFORT, 1810  
 > OD *Bulla gibbosa* LINNAEUS, 1758 <

- = ***Binvoluta*** SCHLÜTER, 1838  
 > M *Ovula gibbosa* LAMARCK, 1810 [= *Bulla gibbosa* LINNAEUS, 1758] <  
 = ***Carinea*** SWAINSON, 1840  
 > M *Bulla gibbosa* LINNAEUS, 1758 <  
***Pellasiimnia*** IREDALE, 1931  
 > OD *Ovulum angasi* REEVE, 1865 <  
***Phenacovolva*** IREDALE, 1930 [*Volva* subgenus]  
 > OD *Phenacovolva nectarea* IREDALE, 1930 [= *Radius brevirostris* SCHUMACHER, 1817] <  
 = || ***Radius*** SCHUMACHER, 1817  
 > M *Radius brevirostris* SCHUMACHER, 1817 <  
 (err. || ***Volvula*** PILSBRY, 1895  
 > TT *Bulla volva* LINNAEUS, 1758 <  
 (err.) ***Volvula*** PILSBRY, 1895  
 = ***Radius*** MONTFORT, 1810  
 > OD *Bulla volva* LINNAEUS, 1758 <  
 = / ***Birostris*** FABRICIUS, 1823 nud., SCHILDER, 1932 syn.  
 = ***Birostra*** SWAINSON, 1840  
 > M *Bulla volva* LINNAEUS, 1758 <

The bold face figures refer to the corresponding bold face numbers of the tribus in the Systematic List

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*Cypraeovulum* 62  
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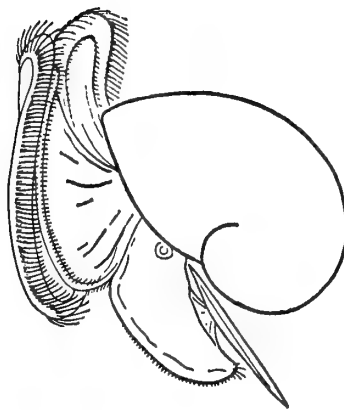
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 ||*Thyreus* 30  
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*Transovula* 82  
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*Triviella* 21  
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*Vulpicella* 51  
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# *Semele martinii* (REEVE, 1853) of Southern Brazil and Uruguay

BY

MIGUEL A. KLAPPENBACH

Museo Nacional de Historia Natural

Montevideo — Uruguay

*Semele martini* WAS PRESENTED and read by ARTHUR ADAMS to the Zoological Society of London on July 12, 1853, but it was not published in the Proceedings until a year later, in July, 1854 (for 1853: p. 97). Meanwhile, it was cited, described and figured by REEVE as *Amphidesma martinii* in November, 1853 (Conch. Icon., spec. 43, pl. 6, fig. 43). It may be noted that REEVE used two "i"s, whereas ADAMS used one in the trivial name. In spite of the fact that REEVE credited the species to ADAMS and made reference to the presentation by ADAMS in the Society in July, 1853, this species must take authorship of REEVE, according to the Rules of Nomenclature. Since then, this species has not been often noted in the malacological literature. We find only a listing of it by PAETEL (1890: p. 63) and a brief footnote by LAMY (1913: p. 354). LANGE DE MORRETES cited it later in his Addenda (1954: p. 43). He had previously not mentioned this species in his Catalog (1949). It is evident that LANGE DE MORRETES was not acquainted with it. However, the brief original description and the figure are quite adequate, and allow us to identify the species.

Recently, this species was rediscovered and redescribed under the name *Semele aurora* TURSCH & PIERRET (1964: p. 35). The description by these authors coincides with the one by REEVE, and the type locality is the same, Rio de Janeiro, Brazil. This is a rare offshore species that probably does not reach the beach, which explains the scant knowledge we have about it. *Semele martinii*, restricted apparently to the Rio de Janeiro area, ranges south to off the Rio de la Plata. The Museo Nacional de Historia Natural of Montevideo, Uruguay, has specimens (single valves) from Maldonado Bay and Lobos Island, Uruguay. They are rather eroded, but identifiable. They reach a larger size than the specimens from Rio de Janeiro.

In the collection of the Academy of Natural Sciences of Philadelphia (no. 313078) there is a specimen, left valve, from La Paloma, Depto. Rocha, Uruguay, in the same condition. Length, 56.0 mm; height, 48.2 mm. Also in the collection of the Academy there is a live-taken specimen from Raza Island, off Rio de Janeiro, Brazil, in 30 fathoms, which measures: length, 40.0 mm; height, 33.6 mm; width, 14.2 mm; the light-brown periostracum is more visible on the anterior and posterior ends. In this specimen it is possible to see the irregular and strong con-

centric folds, often bifurcated, mentioned by REEVE in his original description. These bifurcated folds, among other characters, allow us to separate easily this species from the others recorded from the South American Atlantic coast, namely: *Semele proficua* (PULTENEY, 1799), *S. purpurascens* (GMELIN, 1791), *S. cancellata* (SOWERBY, 1833), *S. (Semelina) nuculoides* (CONRAD, 1841) and *S. casali* DOELLO-JURADO, 1949.

*Semele uruguayensis* PILSBRY, cited by some authors, is the result of the confusion between *Abra uruguayensis* PILSBRY, 1897 (the types of which are in the ANSP, lot no. 70493), and the species that DOELLO-JURADO recently described. *Semele casali* has, according to its author (1949: p. 1), a range that extends along the Uruguayan coast, south to San Matias Gulf in Argentina. However, in the collection of the ANSP (no. 182030) we found a left valve of this species, in good condition, from Carapegus, State of Espirito Santo, Brazil, which extends its distribution to the north approximately 2500 kilometers.

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1854. Descriptions of new species of *Semele*, *Rhizochilus*, *Plotia* and *Tiara* in the Cumingian collection. Proc. Zool. Soc. London (1853) 21: 94-99 (25 July 1854)

### DOELLO-JURADO, M.

1949. Dos nuevas especies de Bivalvos marinos. Com. Zool. Mus. Hist. Nat. Montevideo 3 (57): 1-8; pl. 1

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1964. New species of mollusks from the coast of Brazil. The Veliger 7 (1): 35-37; 5 text figs. (1 July 1964)

# Observations on *Hipponix conicus* (SCHUMACHER, 1817)

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

(Plate 41; 3 Text figures)

SPECIMENS OF THE PARASITIC protandrous hermaphrodite *Hipponix conicus* (SCHUMACHER, 1817) utilized in this study were collected in Fiji, Tonga and the Niue Islands. The specimens occurred as an associated male-female pair in all three localities, parasitic on *Conus mustelinus* HWASS in BRUGUIÈRE, 1792, *Mitra coffea* SCHUBERT & WAGNER, 1829, *Strigatella decurtata* (REEVE, 1844) and *Bursa granularis* (RÖDING, 1798). The four hermaphroditic specimens were attached directly to *Mitra coffea*, *M. stictica* (LINK, 1807), *Conus striatus* LINNAEUS, 1758 and *C. omaria* HWASS in BRUGUIÈRE, 1792.

All specimens were collected in shallow water, from 0 to 5 feet in depth. The specimens examined were as shown in Table 1.

Fijian specimens of *Hipponix conicus* were examined in the living state, while the Tongan and Niue Island specimens were received preserved in spirits. A *post mortem* change in preserved specimens was a uniform brown discoloration of all soft parts. The six female specimens, all twice as large as the small males, and the four hermaphroditic specimens were attached to the shell-surface of their host; the seven small males were sedentary on the females.

## TAXONOMY

### *Hipponix* DEFRANCE, 1819

1817. *Amalthea* SCHUMACHER, Essai nouv. syst., pp. 56, 181.—Type species by SD (GRAY, 1847) *A. conica* SCHUMACHER, 1817 (non *Amalthea* RAFINESQUE, 1815)

1819. *Hipponix* DEFRANCE, Journ. Physique et Chim. 8: 217—Type species by OD "H. mitrata GMELIN" (error for *mitrula* GMELIN, 1791) = *Hipponix antiquatus* (LINNAEUS, 1767)

1819. *Hipponyx* [sic] DEFRANCE, BLAINVILLE, Bull. Sci. Soc. Philom., p. 9

1841. *Sabia* GRAY, Syn. Cont. Brit. Mus. ed. 43, p. 126 [nom. nud.]

1842. *Sabia* GRAY, Syn. Cont. Brit. Mus. ed. 44, p. 90 [nom. nud.]

1847. *Sabia* GRAY, Proc. Zool. Soc. London, p. 157—Type species by OD *Amalthea conica* SCHUMACHER, 1817

1906. *Malluvium* MELVILL, Proc. Malac. Soc. London 7: 81-84  
Type species by OD *Capulus lissus* E. A. SMITH, 1894

Table 1

Specimen No.	Size in mm	Sex	Spawn	Host species	Position	Locality <sup>1</sup>
1	20.5	♀	+	<i>C. mustelinus</i>	apex of spire	F
2	11.5	♀	+	<i>B. granularis</i>	body whorl	F
3	11.3	♀	+	<i>S. decurtata</i>	body whorl	N
4	10.7	♀	+	<i>M. coffea</i>	labial lip	T
5	10.1	♀	+	<i>M. coffea</i>	penult whorl	T
6	9.5	♀	+	<i>M. coffea</i>	antepen. whorl	T
7	9.4	♂	—	<i>C. striatus</i>	spire	F
8	8.0	♂	—	<i>C. omaria</i>	spire	F
9	7.8	♂	—	<i>M. stictica</i>	penult whorl	N
10	7.6	♂	—	<i>M. coffea</i>	labial lip	T
11	4.9	♂	—	<i>H. conicus</i> ♀	dextral side	N
12	4.9	♂	—	<i>H. conicus</i> ♀	dextral side	F
13	4.4	♂	—	<i>H. conicus</i> ♀	dextral side	T
14	4.2	♂	—	<i>H. conicus</i> ♀	dextral side	F
15	3.7	♂	—	<i>H. conicus</i> ♀	dextral side	T
16	3.3	♂	—	<i>H. conicus</i> ♀	dextral side	T
17	2.2	♂	—	<i>H. conicus</i> ♀	dextral side	F

<sup>1</sup> F — Fiji; N — Niue Island; T — Tonga Island

### *Hipponix conicus* (SCHUMACHER, 1817)

1817. *Amalthea conica* SCHUMACHER, Essai nouv. syst. p. 181, plt. 21, figs 4a, 4b, 4c

1819. *Patella australis* LAMARCK, Anim. sans vert. 6: 335

1830. ? *Pileopsis paleacea* MENKE, Syn. meth. Moll., p. 147

SCHUMACHER, 1817, established *Amalthea* for the species *A. conica* SCHUMACHER, 1817 and *A. maxima* SCHUMACHER, 1817 [= *Capulus ungaricus* (LINNAEUS, 1758)]. *Capulus ungaricus* (LINNAEUS) has already been appropriated as the type-species of *Capulus* MONTFORT, 1810,

and *Amalthea conica* was subsequently designated by GRAY (1847, p. 157) as the type species of *Amalthea*. SCHUMACHER's genus name, however, is a homonym of *Amalthea* RAFINESQUE, 1815, and therefore not available.

The DEFRANCE reference appears to be a scarce journal which is not available to me and is lacking in the Australian and Auckland Museums; entries have been compiled from SHERBORN (1902-1933) and E. A. SMITH (1906). SMITH, who obviously consulted the original reference, states that "*Hipponix mitrata* GMELIN," which presumably is a *lapsus* for *H. mitrula* (GMELIN), was designated as the type-species of *Hipponix* by DEFRANCE in the original publication. *Hipponix mitrula* (GMELIN) is synonymous with *H. antiquatus* (LINNAEUS). "*Hipponyx*" BLAINVILLE is only a misspelling of *Hipponix* DEFRANCE in a later publication (*vide* synonymy). Since the type-species of *Hipponix* has been originally designated, GRAY's subsequent designation (op. cit., p. 157) of *Patella cornucopiae* LAMARCK, 1803 (Eocene fossil from the Paris Basin) as the type species of *Hipponix* is invalid.

GRAY (op. cit., p. 157) established the genus *Sabia* through publication in synonymy of *Amalthea* SCHUMACHER; the type-species therefore is also *A. conica* SCHUMACHER by original designation. GRAY himself quoted *Sabia* as of 1833, but this reference appears untraceable; on two occasions *Sabia* appeared as a *nomen nudum*.

MELVILL, 1906, established *Malluvium* as a subgenus of *Amalthea* SCHUMACHER for the deep-water species *Capulus lissus* E. A. SMITH, from the Bay of Bengal. The author laid stress on the absence of radiating sculpture of *C. lissus*, which he stated is present in all specimens of either *Amalthea* SCHUMACHER or *Capulus* MONTFORT. SMITH (op. cit.) regarded MELVILL's *Malluvium* as "premature if not unnecessary," and correctly pointed out that the presence or absence of a concentric or radial sculpture in this group of species is hardly sufficient for the erection of a new subgenus. SMITH's contention must be supported in view of the presence of smooth and heavily ribbed or concentrically lamellated specimens of *Hipponix conicus* in even the short series of specimens used in this study. THIELE, 1903, figured the radula of "*Hipponix lissus*," which is basically similar to the radula of *H. conicus*, and included it in the family Capulidae. E. A. SMITH (op. cit.) remarked that Professor Gwatkin studied the radulae of *Capulus lissus* and pronounced them to be nearest *Amalthea* SCHUMACHER.

Taxonomy on the specific level appears to be equally confused in view of the great variability of conchological characters, i. e. colour, form and sculpture of *Hipponix conicus*; several currently acceptable specific names may

prove to be synonyms in a detailed comparison survey. E. A. SMITH (op. cit.) synonymized *Patella australis* LAMARCK with *Hipponix conicus*, and regarded LAMARCK's name to be of prior date without mentioning the year of authorship. I was unable to trace *Patella australis* LAMARCK prior to 1819. THIELE, 1925, equates *H. acutus* QUOY & GAIMARD, 1835 with *H. conicus* (SCHUMACHER).

There is no unanimity of opinion among malacologists as to a suprageneric classification of the group of related hermaphroditic taenioglossate gastropods. THIELE, 1929, placed the cap-shaped, non-operculate parasitic and hermaphroditic Amaltheidae (= Hipponicidae) together with operculate, spirally coiled and sometimes viviparous Fossaridae, and operculate and dioecious Vanikoroidae in the superfamily Amaltheacea (= Hipponiceacea). Families with similar shells, anatomy, oviposition and sexes to the Hipponicidae, e. g. Capulidae and Calyptraeidae, were placed by THIELE with operculate and dioecious Trichotropidae and operculate Amaplocamidae in the superfamily Calyptraeacea.

Hipponicidae show a considerable similarity to Capulidae: they are similar in shell-form, having a high-peaked, cap-shaped shell which lacks an internal apical plate. Both are sedentary parasitic or semi-parasitic hermaphrodites, with the females retaining their brood within the shell and veligers spawning as echinospiral veligers. Their radulae are so similar that in other groups of gastropods they would not be considered to exceed generic level. Species of the hipponicid genus *Cheilea* MODEER, 1793, are more dissimilar to *Hipponix* than the latter is to *Capulus*. *Cheilea* species are parasitic on rocks, the animal's proboscis is slender and longer and lacks the side-flaps near the mouth; the rhachidians of the radula are wing-shaped, and the interior of the shell has an horse-shoe shaped, moderately long and shelly plate extension; females retain their spawn within the shell, and males are often found attached to the females.

The difference between Capulidae and Hipponicidae appears to be mainly in the mode of feeding and host selection. *Capulus* is reported to be a ciliary feeder and generally prefers bivalves for hosts. SCHEPMAN, 1909, however, reports *C. danieli* CROSSE, 1858, attached to "*Gyrineum cuspidatum* REEVE." These differences are few and doubtfully exceed family or superfamily level of classification. The present classification appears to be a retention of an orthodox taxonomic arrangement and not a superfamilial separation based on tangible evidence. *Hipponix conicus* would be more appropriately placed somewhere close to Capulidae, within the superfamily Calyptraeacea, and not in the Hipponiceacea.

## THE SHELL AND POSITION OF ATTACHMENT

The species *Hipponix conicus* is rather variable in form, colour and sculpture. The outline of the shell margin generally corresponds with the shell-surface of its host. Some specimens are high and cap-shaped, with a curved and obsoletely coiled apex which protrudes slightly over the posterior shell margin; other specimens are oval, elliptical, round or irregularly pentagonal in outline from a ventral view. The apex can be displaced as much as  $\frac{1}{3}$  of the shell-length towards the centre, and viewed in profile some specimens appear rather depressed. Shells are sculptured with 15 - 34 flattened radial ribs, while in some small males ribs are completely absent. The concentric lamellations and coiled apex are generally obsolete in female shells, but quite distinct in some males; the radial ribs form a scalloped shell-margin. The exterior of the shell is either white, dirty grey, partly white and reddish-brown or white with reddish-brown rays. The interior of the shell is either pure white, white with orange muscle-scars, white with brown stains towards the apex or bluish-white with traces of brown muscle scars. Females are twice as large as the males, and hermaphroditic specimens are only slightly smaller than the females.

In all specimens examined, the females and hermaphrodites were attached directly to their hosts while the small males were sedentary on the females. The female will occupy almost any position on the host's shell-surface, with the exception of the area on the dorsal centre axis. The small males were fastened to the dextral side of the female

shell, and close to the shell margin, with the apex facing in the general direction of the female's apical region. Prominent scars are left on the host which correspond closely to the internal anatomy of the parasite. The scalloped shell margin is clearly indented in the host's shell-surface, the surrounding area is shallow and oval and rises to a small elevated plateau which has a central depression for the reception of the foot. The same type of scars are visible on the female *Hipponix* where the males were attached.

Restricted locomotion is evident in the species prior to reaching the required position of final immobility; one small male was somewhat too far away from the female's shell margin and subsequently moved into position, leaving a well-defined track in the female's shell-surface. HARTLEY (1958) discussed locomotion of *Hipponix conicus* and illustrated tracks of the species on the dorsal surface of *Haliotis ruber* LEACH, 1815. Once in position, it appears that the animal becomes immobile and temporarily sedentary. There is no evidence of hole-boring in *Hipponix conicus*; the small hole visible near the anterior margin of the labial lip on *Mitra coffea* is irregular, and has been caused through the softening process of the animal's body during deposition on a thin part of the host's shell.

## THE ANIMAL

The animal's foot is small, disc-like, and fawn in colour; the mantle and horse-shoe shaped muscle are yellow in colour. The head is long when extended, thick and brownish-grey in colour; two short, curved and pointed flaps

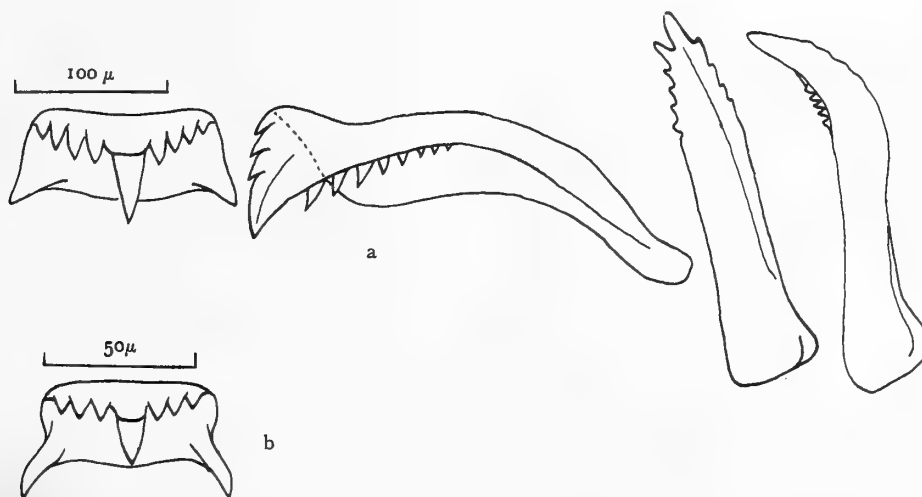


Figure 1

*Hipponix conicus* (SCHUMACHER)

a. Half row of radular teeth of female specimen No. 1

b. Rhachidian of radula of male specimen No. 14

Fiji Islands

are situated on each side of the animal's head. The head moves steadily from side to side and at times exposes the proboscis, displaying the whole length of the radular ribbon, vertically to the axis of the body, from the roof of the mouth to the floor of the mouth. Tentacles are long, moderately stout, yellow in colour, and either laterally streaked with purplish-brown or fully dark purple at the distal end. Eyes are small and simple and placed dorsally on the body near the junction of the tentacles and close to the tentacle's margin. The penis, where observed, was either moderately short or rudimentary, and cream in colour. An operculum is absent.

### THE RADULA

The radula is taenioglossate, short and broad in the female, translucent-white in colour, formula  $2 \cdot 1 \cdot 1 \cdot 1 \cdot 2$ . Rhachidians are broader than they are long, and equipped with a long central cusp which extends past the plate-margin; four smaller accessory cusps are positioned on either side of the main cusp. Lateral teeth are very broad, with a large main cusp and eight accessory denticles on the cutting edge of the main cusp. Inner marginals have six denticles, outer marginals about 5 denticles on the cutting edge of the main cusp. The female's radular ribbon measured 1.70 mm in length, 0.74 mm in width in an animal with a shell 20.5 mm in length; the ribbon contained 32 fully formed rows of teeth and 6 nascentes. Considerable wear on the teeth was evident in the front rows and persisted to the 12<sup>th</sup> anterior row. The considerable wear on the teeth and rather large proportion of nascentes to fully formed teeth would indicate frequent use of the radula on hard substratum.

The radulae of small males differ in minor but significant points from those of the females. In one male the radular ribbon measured 1.12 mm in length and 0.26 mm in width in an animal with a shell 4.2 mm in length; radulae of other males differ only slightly in proportion. The rhachidians of the radula have a slightly shorter central cusp and only three accessory denticles, while the laterals have only seven denticles on the cutting edge. The

marginal pegs on rhachidians are longer and more prominent, and the ribbon contains about 53 rows of fully formed teeth and only 1 to 2 nascentes.

The radular ribbon of the males is longer in proportion to shell-length than that of the female (male: 37.5% of length; female 12% of length), and the ribbon is more

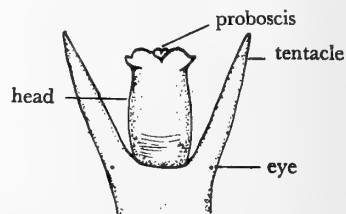


Figure 2

*Hipponix conicus* (SCHUMACHER)

Dorsal view of anterior part of animal

slender in proportion to total ribbon-length (male: 23%; female: 43%). No wear whatsoever was evident in the male radulae and the cusps of the first anterior row were as sharp as those in subsequent rows; the number of nascentes is reduced accordingly.

### EGG CAPSULES AND VELIGERS

Egg-capsules are retained within the parent's body and are attached to the underside of the animal. Six females contained spawn, while only brood-sacs were present in hermaphroditic specimens. The female specimen from Fiji contained 36 elongated, vase-shaped capsules which are translucent-cream in colour; each capsule contained on the average 300 ova, which would be about 11 000 ova in the spawn. Capsules were attached by fine but strong filaments to a central brood-sac, which contained round ova of varying sizes, measuring from  $15 \mu$  -  $30 \mu$ . Eggs in the capsules were in different stages of development, some having reached an early veliger stage, while others were in the trochophore phase. Both trochophores and veligers measured from  $120 \mu$  -  $150 \mu$ . Early veligers had a cepha-

### Explanation of Plate 41

Figure 1: Ventral view of living animal of *Hipponix conicus* (SCHUMACHER): view of female specimen No. 1, showing egg capsules, tentacles and extended head.  $\times 4.0$

Figure 2: Female *Hipponix conicus* specimen No. 1 carrying male specimen No. 12, *in situ* on *Conus mustelinus* HWASS in BRUGUIERE  $\times 1.3$

Figure 3: Female *Hipponix conicus* specimen No. 4 carrying male specimen No. 13, and hermaphroditic specimen No. 10 attached to labial lip margin of *Mitra coffea* SCHUBERT & WAGNER.  $\times 2.5$

Figure 4: Etched out shell-scars on *Mitra coffea* after removal of *Hipponix conicus* specimens.  $\times 2.6$

Figure 5: Dorsal and ventral view of female *Hipponix conicus* specimen No. 5 carrying male specimen No. 15.  $\times 2.5$

Figure 6: Lateral view of specimens No. 5 and No. 15.  $\times 2.5$

Figure 7: Dorsal and ventral view of female *Hipponix conicus* specimen No. 1 carrying male specimen No. 12.  $\times 2.1$

Figure 9: Lateral view of specimens No. 1 and No. 12.  $\times 2.1$

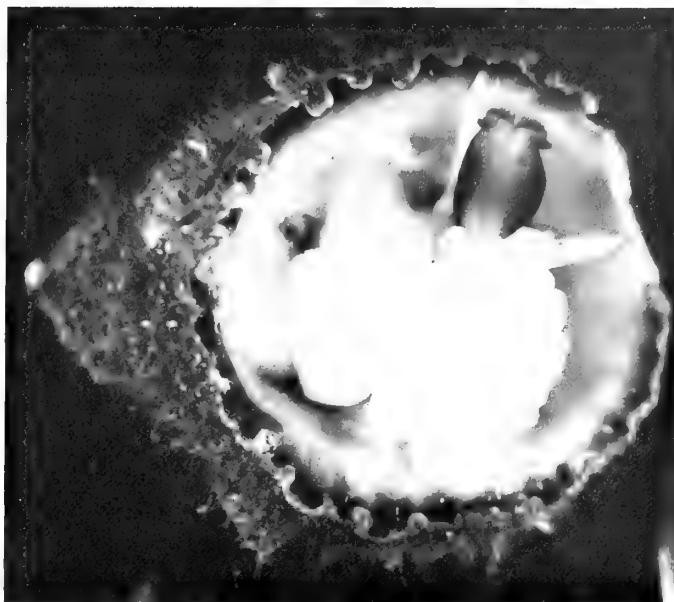


Figure 1

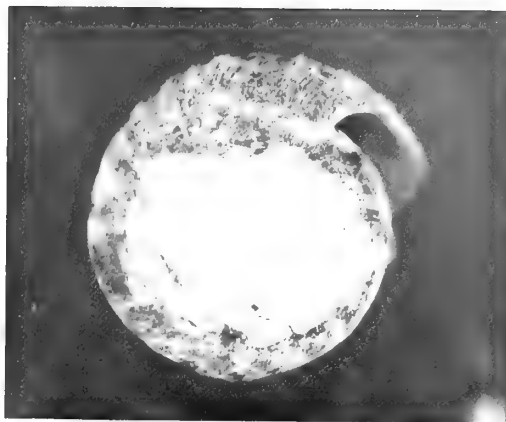


Figure 2



Figure 3



Figure 4

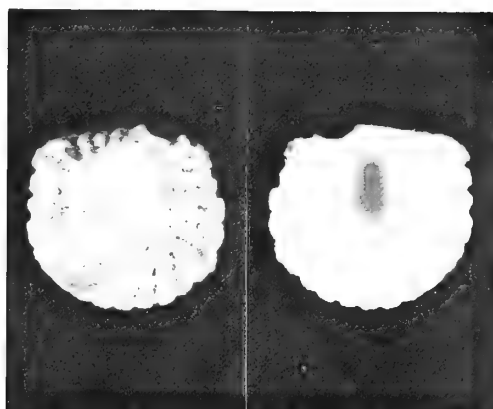


Figure 5



Figure 6

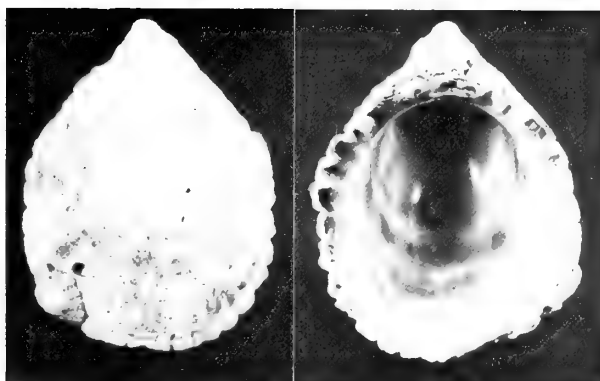


Figure 7

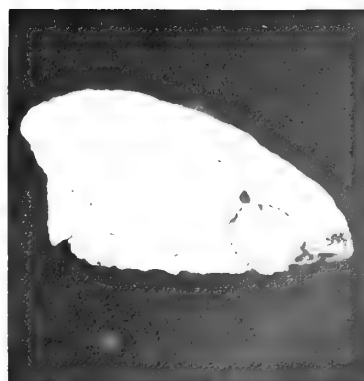


Figure 8



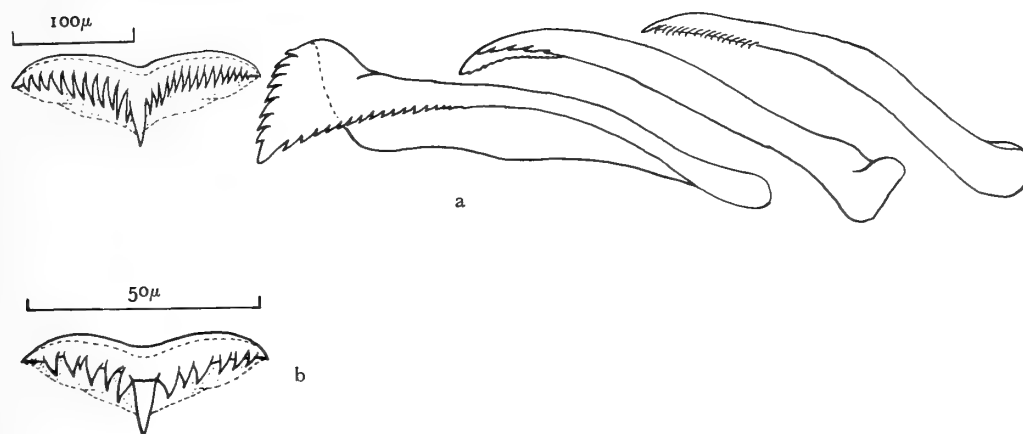


Figure 3

*Cheilea equestris* (LINNAEUS)

- a. Half row of radular teeth of a female specimen  
 b. Rhachidian of radula of a male specimen parasitic on the female  
 Fiji Islands

lopedal mass of transparent cells and a transparent embryonic shell. Some of the liberated veligers were free-swimming and vigorously active, while others were stationary but rotating freely within the fluid.

#### FEEDING HABITS

The actual feeding process was not observed and deductions can be made only from evidence on hand. The unworn radula of the male shows that he is not a detritus feeder and does not abrade on hard substrata. He does not only position himself on the female's dextral marginal edge solely for the purpose of fertilization but possibly also for feeding purposes. The male either subsists on particles of food gathered by the female or even feeds on her faecal pellets which are regularly discharged and maneuvered to the same marginal edge where the male is reposing.

#### FAECES

The gut contained loose faeces as well as formed faecal pellets. During examination of the living animal, faecal pellets in groups of 4 - 5 were discharged by the female in about 20 minute intervals; pellets are "0"-shaped, greenish-brown and about 1.0mm long. They contain mucus and a predominance of solids, *e. g.* coral, sand

grains, algae, some fragments of radiolarians and some unidentified regular and slender spicules. In one specimen a rather large and cuboidal piece of sand grain was reposing in the gut.

#### DERMATOPTIC PERCEPTION

The living animal was turned over onto its shell, with the internal organs facing the light source, but eyes well shielded from the light source by the interposing body. The animal's head was moving freely, but it violently retracted its head extension as soon as the impact of the shadow fell on its body. It was thought at first that the closeness of the hand may have been sensed by other means than dermatoptical ones, and a sheet of clear glass was placed between the light source and brought close to the animal's body; it failed to elicit a quick withdrawal of the head. The variation of light intensity may therefore be perceived by the animal through the skin alone or may be sensed by minute eye-sensors (as in Chitonidae) as yet not recognized.

#### SUMMARY

*Hipponix conicus* (SCHUMACHER) is a parasitic protandrous hermaphroditic mesogastropod which is not host-specific. Shells are small, about 2 mm to 21 mm in length,

generally cup-shaped or conforming in shape to the shell substratum of its host; shells are rather colorless, smooth or sculptured with radial ribs or occasionally concentric rings. The radula is taenioglossate. Males and females occur in associated pairs with the females parasitic on a gastropod and the males attached to the female *Hipponix*. Evidence suggests that the species begins its first sexual phase as a small male fastened to the female's dextral shell margin for fertilization and possibly faecal pellet feeding. The species then gradually passes into the hermaphroditic stage when it grows larger, intermediate in size between males and females, and settles directly on the main host. In the final female stage the species is completely sedentary and has developed a larger shell, capable of accommodating the brood-sac and spawn which is retained within its body. Veligers are free-swimming and echinospira.

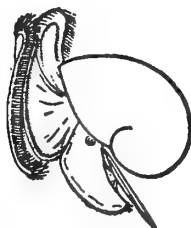
*Hipponix conicus* has a wide distribution ranging from East Africa through the Indo-Pacific to Japan, the Hawaiian Islands and the Tuamotu Archipelago.

#### ACKNOWLEDGMENTS

I would like to thank Dr. A. W. B. Powell, Auckland Institute and Museum, and Dr. D. F. McMichael, Australian Museum, Sydney, for their assistance with literature references. The preserved material received from Mr. H. C. Gay, Nuku'alofa, Tonga and Mr. N. McDowall, Niue Island, has been much appreciated.

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Notes on the Range Extension  
of the Boring Clam *Penitella conradi* VALENCIENNES  
and its Occurrence in the Shell of the California Mussel

BY

STEVEN E. MEREDITH

Department of Zoology, Oregon State University, Corvallis, Oregon 97331  
and

Oregon State University Marine Science Center, Newport, Oregon 97047

(Plate 42)

THE STUDY REPORTED ON herein was conducted at the Haystack Rock area, Cannon Beach, Clatsop County, Oregon, Latitude 45° 53' 04" N, Longitude 123° 58' W. Investigations were carried on seasonally throughout 1964 as a part of the studies for a master's thesis at the University of Puget Sound, Tacoma, Washington, and again in the summer of 1966, while the writer was in residence at the Oregon State University Marine Science Center, Newport, Oregon.

The range of *Penitella conradi* VALENCIENNES, 1846 was previously reported to be from Bahía San Bartolomé, Baja California, Mexico, to Gualala, Mendocino County, California (TURNER, 1955). This species has not previously been reported in Oregon, and this report represents a considerable extension of its northern range limit. TURNER reported finding *P. conradi* in the shells of various mollusks, including *Mytilus californianus* CONRAD, 1837, in California. This species is very commonly found infesting species of *Haliotis* (abalones) and has been commonly referred to as the "*Haliotis* borer."

The mussel beds at Cannon Beach attain a maximum vertical width of approximately 7 feet on the rock faces, and a check of several hundred *Mytilus* revealed that *Penitella* is restricted to the lowest 2 feet of the beds. A thorough examination of 113 mussels showed that the percentage of infestation was approximately 20%. The number of borers per host ranged from 1 to 11, with an average of 3.8.

*Penitella conradi* invades the mussel when quite young and grows considerably as it bores slowly into the valve, thus creating a conically-shaped burrow. The entry holes range in size from less than 1 mm to 2 mm in diameter and are often difficult to detect, especially if the mussel valves are heavily fouled with such organisms as barnacles, tubiculous polychaetes, etc; therefore, a fast and reliable method of determining whether or not the borer is present is to open the host, remove the soft tissues, and examine the inner surface of the valves. The presence of the invader is evidenced by patches of black, leathery conchylin, laid down in response to the boring activities (Plate 42, Figure 1). In many cases the conchylar patch is surrounded by a thickened, warped area of the valve. Occasionally, where there is multiple infestation in a limited area of the valve, warping may be so severe as to nearly occlude the mantle cavity; however, such mussels appear otherwise normal.

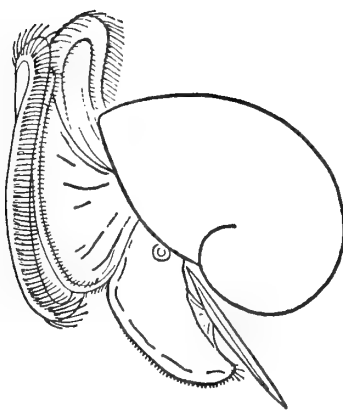
Removal of the borer from its burrow intact may be accomplished with the careful aid of a hammer and chisel by fracturing the host's valve immediately adjacent to the burrow; this will usually lay open the burrow without harming the borer, which can then be removed gently with forceps. In one instance this procedure fortunately revealed both an immature and an adult stage of *Penitella* (Plate 42, Figure 2), the former being larger than the latter in this case. The immature stages of *P. conradi* and other pholads are characterized by gaping valves and a large,

muscular foot, both vital in the boring process. Upon attaining the adult stages, the animal ceases boring, becomes sessile, and the area between the valves becomes closed off by a thin, calcareous layer known as a callum. This striking change in morphology during the life cycle of the animal has lead to considerable confusion in the taxonomy of pholads in the past, e. g., the immature, boring stage of *P. conradi* was previously described and well known as *Navaea subglobosa* GRAY, 1851.

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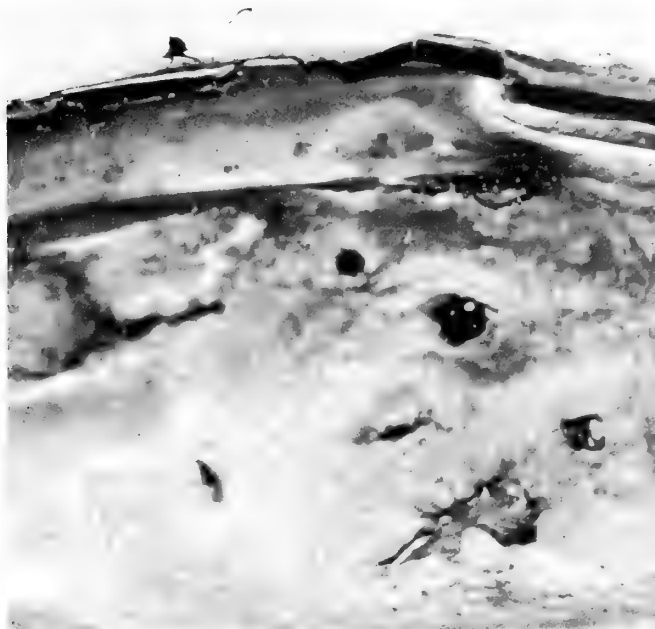


Figure 1: Interior of the valve of *Mytilus californianus*, showing the dark patches of conchyolin laid down in response to the boring activity of *Penitella conradi*, which lie immediately behind the patches (x 1.5)



Figure 2: A cross section of the valve of *Mytilus californianus*, showing the two major stages in the life cycle of *Penitella conradi*. In this instance the immature stage individual is the larger. The gaping, toothed valves of the boring (immature) individual are obvious, as is the callum of the mature stage, closing off the anterior end of the sessile (adult) individual (x 5)



# A Radula Muscle Preparation from the Gastropod, *Kelletia kelletii*, for Biochemical Assays

BY

HOWARD M. FEDER

Hartnell College, Salinas, California 93901

AND

REUBEN LASKER

United States Bureau of Commercial Fisheries

California Current Resources Laboratory, La Jolla, California 92037

(1 Text figure)

THE MUSCLE BUNDLES, the odontophore muscle complex or radula muscle, which move the molluscan radula have been physiologically examined in isolated preparations from two species of carnivorous gastropods: *Busycon canaliculatum* (LINNAEUS, 1758) (HILL, 1956, 1958), a snail from the east coast of North America, and *Buccinum undatum* LINNAEUS, 1758 (FÄNGE & MATTISON, 1957, 1958), a snail common to European waters. These authors found that the muscle contracts under the influence of acetylcholine and is relaxed by 5-hydroxytryptamine and that rhythmic contractions of the muscle occur when acetylcholine and 5-hydroxytryptamine are added together. FÄNGE (1963) and FEDER & ARVIDSSON (1967) showed that aqueous extracts of the sea stars *Henricia sanguinolenta* (MÜLLER, 1776), *Marthasterias glacialis* (LINNAEUS, 1758) and *Asterias rubens* LINNAEUS, 1758 also induce strong contractions in the isolated radula muscle of *Buccinum undatum*. Because of the usefulness of this kind of radula muscle preparation for bioassay we sought one from a gastropod of the American west coast. This paper reports on the preparation and use of the radula muscle from the carnivorous snail *Kelletia kelletii* (FORBES, 1850) for biochemical assays.

*Kelletia kelletii* were collected by means of SCUBA at a depth of about 20 m on sandy ocean bottom, near the Scripps Institution of Oceanography, La Jolla, California. The bathymetric range of *K. kelletii* is known to extend from 18 to 62 m (ABBOTT, 1954). Some of the *Kelletia* were subsequently shipped to Hartnell College and used in experiments there. The radula muscle was prepared and

mounted by a modification of the techniques of FÄNGE & MATTISON (1958), FÄNGE (1963), MATTISON & ARVIDSSON (1966), and FEDER & ARVIDSSON (1967) for isolating the radula muscle complex of *Buccinum undatum*. The final *Buccinum* muscle preparation included part of the proximal proboscis sheath which served for suspension of the muscle. *Kelletia* radula muscles prepared in this manner tended to behave erratically and showed a decreased sensitivity as compared to *Buccinum* radula muscles. This fact necessitated that the *Kelletia* radula muscle and the inner epithelial lining of the proboscis sheath be teased free of the sheath; the resulting preparation was more responsive and less erratic. The preparation was then suspended directly from the epithelial lining to the recording lever (Figure 1). The chamber was a plastic 30 cc syringe with the outlet enlarged to permit a rapid outflow when it was flushed. A lever with an arm 18 cm long and counterweighted with 2.0 g was used. The writing stylus was a fine glass rod of capillary size with a rounded tip. The muscle was mounted to the lever at its proximal end by a cotton thread through the epithelial tissue and to the glass rod at its oral end by a small loop from the radula sheath tissue. During perfusion sea water was either removed by aspiration or allowed to overflow the chamber. All other details of the experimental setup were the same as those described for radula muscle preparations of *Buccinum undatum* by FEDER & ARVIDSSON (1967).

Specimens of the sea star *Pisaster ochraceus* (BRANDT, 1835) were taken either from pilings off the pier at Scripps Institution of Oceanography, or from rocky reefs off La

Jolla, and from intertidal areas in Monterey Bay, California. The sea star *Pycnopodia helianthoides* (BRANDT, 1835) was collected in intertidal areas in Monterey Bay. Extracts were obtained by the same procedures used by FEDER & ARVIDSSON (1967) for the preparation of *Marthasterias glacialis* test solutions. Living sea stars were washed in tap water, frozen, and then thawed; the resultant cloudy exudate was collected and centrifuged. The clear supernatant fluid was used in all tests.

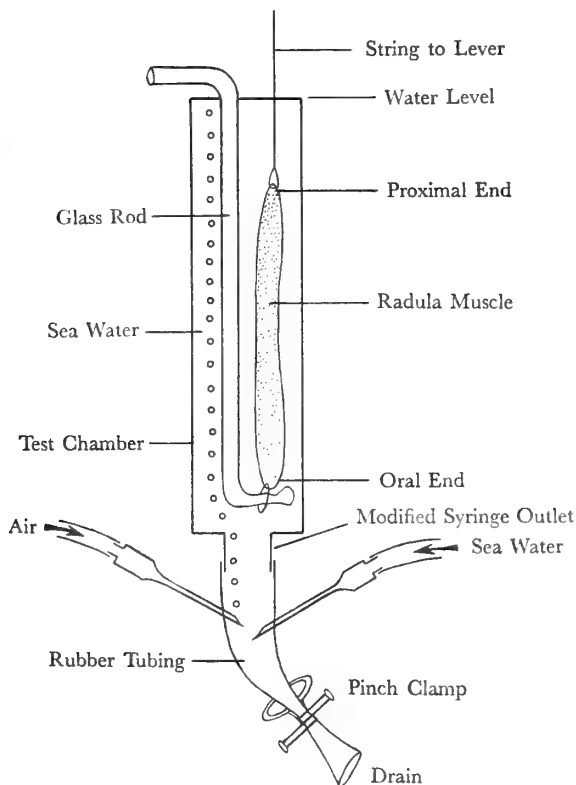


Figure 1

Diagram of the mounted radula muscle preparation

The *Kelletia* radula muscle contracted in the presence of acetylcholine of which the final concentration was  $5 \times 10^{-8}$  g/ml. Extracts of *Pisaster ochraceus* also caused the radula muscle of *Kelletia* to contract; the strength of the contractions varied roughly with amount of extract added. After addition of acetylcholine or *P. ochraceus* extract the contraction could be reversed immediately by

$3 \times 10^{-7}$  g/ml (final concentration) of 5-hydroxytryptamine. Strong, rhythmical contractions followed the initial relaxation. Similar responses of *Kelletia* muscle to *Pycnopodia* extracts were found in preliminary experiments. Responses, however, were always of greater magnitude to *Pycnopodia* than to *Pisaster ochraceus*, whether as contractions in response to the extracts or rhythmic contractions in response to the extracts after addition of 5-hydroxytryptamine. The amplitude of muscle contraction after addition of *Pycnopodia* extract was 2 to 3 times greater than that caused by addition of identical volumes of *Pisaster ochraceus* extract.

Sensitivity of muscles varied with time; in general, older preparations, 24–48 hours old maintained in a water bath at 10° C, were more sensitive. In addition, muscle preparations responded only when a certain "threshold" concentration (40 microliters in a final volume of 30 ml of sea water) of *Pisaster* extract was reached. An addition of sea star extract 5 times the threshold amount (i. e. 200 microliters in a final volume of 30 ml of sea water) frequently caused an extremely strong contracture from which the muscle often did not recover when the sea water in the bath chamber was renewed. Thus, like *Buccinum* muscle preparations, responses were quantitative only within a narrow range of extract additions.

The successful isolation of the radula muscle complex of *Kelletia kelletii* and its subsequent use in assay increases the number of available preparations of this type to three; *Busycon canaliculatum* and *Buccinum undatum* represent the other two species. The *Kelletia* preparation is very similar to that of *Buccinum*, and the responses of the radula muscles of the two species also are similar. It is probable that other carnivorous snails have radula muscles suitable for physiological and pharmacological studies.

## ACKNOWLEDGMENTS

This work was supported by a National Science Foundation Research Participation Grant to one of us (H. M. F.), and was accomplished at the Bureau of Commercial Fisheries, Fishery-Oceanography Center, La Jolla, California. We thank Mr. Daniel Tam of Hartnell College and Mr. William Vlymen of the Scripps Institution of Oceanography for their very able technical assistance, and Mr. George Crozier of the Scripps Institution of Oceanography and Mr. Robert Bowers of the Scripps Tuna Oceanography Research Program for collection of experimental animals.

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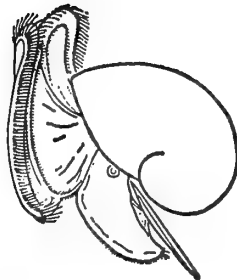
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# A Remarkable New Cancellariid from the Philippines, with Comments on Other Taxa

(Gastropoda : Volutacea)

BY

WILLIAM E. OLD, Jr.

Department of Living Invertebrates American Museum of Natural History  
Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 43; 2 Text figures)

SOME TIME AGO Mr. and Mrs. Clifford Ames, who reside in the Philippines, submitted to us a specimen of a cancellariid which had been taken by Mr. Mario Mercado during trawling operations off Marinduque Island, Philippines. This distinctive gastropod apparently is an undescribed species. It does not seem to have been reported by SCHEPMAN (1908-1913) from the collections of the "Siboga" trawled in Indonesian waters, nor is it represented in the extensive deep water dredgings of the "Albatross" in Philippine waters, which are now housed in the U. S. National Museum, Smithsonian Institution. The species is named in honor of the collector, Mario Mercado.

*Scalptia* JOUSSEAUME, 1887

Type species: *Scalptia obliquata* LAMARCK, 1822, by OD.

WENZ (1938) considered *Scalptia* to be a subgenus of *Trigonostoma* BLAINVILLE, 1827, of which the type species is *Delphinula trigonostoma* LAMARCK, 1822, by M and tautonymy. More recent workers, notably HABE (1961a and 1961b; 1964), HABE & KOSUGE (1966) have accorded *Scalptia* full generic recognition.

*Scalptia mercadoi* OLD, spec. nov.

(Plate 43, Figures 1 to 3; Text figures 1 and 2)

**Description of Holotype:** (Plate 43, Figure 1) Shell ovate, with an extended spire forming an angle of 50°. Aperture less than one half the length of the shell. Shell measuring 34+ mm in length; 19 mm in width. Shell of 6½ whorls. Nucleus of about 2½ whorls (partially missing in the holotype). Nuclear area and first two post-embryonic

whorls translucent, due to cleaning. Body whorl ornamented with 9 large raised ribs. Ribs rather narrowly attached, excavated on both leading and trailing edges. Excavation deeper on leading edge. Penultimate whorl with 10 raised ribs. Ribs truncate posteriorly, and sutures deeply channeled. Sutures bridged by posterior margin of old varices, which connect with the varix obliquely above (see Text figure 1).

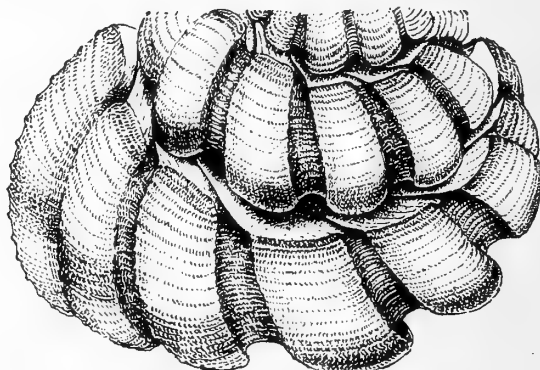


Figure 1

*Scalptia mercadoi* OLD, spec. nov.

Enlargement of body whorl and penultimate whorl of holotype showing detail of sutures; x 4

Drawing courtesy of Mr. Anthony D'Attilio

Ribs on body whorl ornamented with raised, spiral threads, commonly 22 in number and with one or more weaker threads between. Interstices of ribs also with transverse threads, from 22 to 24 in number. Interstices

also ornamented with fainter axial sculpturing, imparting a delicate cancellate effect. Profile of rib strongly convex, thickest near the trailing edge, and convexity diminishing towards the leading edge.

Umbilicus deep and profound, entered by anterior attachments of ribs.

Aperture elliptically ovate, with 8 raised spiral cords on outer wall. Exterior ribs are visible as axial lines. Posterior canal with one strong, grooved rib. Three spiral plaits on columella, of which the uppermost plait is the strongest.

Color of shell light orange. Body whorl ornamented with 2 conspicuous bands of light purplish-brown, one at periphery, the other between the periphery and the anterior angulation of the ribs. A third, fainter band of pigmentation is indicated at posterior or uppermost angulations of ribs. Aperture bluish-white, shading to light orange on the columella.

From a portion of the partially decomposed animal, the holotype was determined to be a male.

Periostracum unknown.

**Type locality:** Trawled in 175 fathoms, off Gasan, Marinduque Island, Philippines. November 2, 1965.

**Type depository:** American Museum of Natural History, no. 138276.

**Descriptions of paratypes:** Paratype "A." (Plate 43, Figure 3). Shell of 35.4 mm in height, 18.5 mm in width. Shell of  $8\frac{1}{2}$  whorls. Nucleus intact, and consisting of  $2\frac{1}{2}$  whorls. Nucleus polished and tan in color. Body whorl with 10 ribs, more crowded than those of the body whorl of the holotype. It was collected in Tayabas Bay, Quezon, Philippines, on November 14, 1966. Paratype "A" in collection of Mr. and Mrs. Crawford N. Cate, no. CA 107, ex Romeo Lumawig.

Paratype "B" (Plate 43, Figure 2) measures 26 mm in height and 16.4 mm in width. The coloration is darker than in either of the other specimens, the transverse bands being of a dark purplish-brown, and the orange pigmentation is more livid. The interstices are suffused with solid purplish-brown, the transverse banding being faintly discernible as darker coloration. The umbilicus is almost completely closed. The columella is colored a pale orange shading to dark purplish-brown in the area of the plaits. It was trawled in 120 fathoms, Tayabas Bay, Luzon, Philippines, in 1966. The radula of this specimen was extracted and sketched by Mr. Masao Azuma (see Text figure 2). Paratype "B" in the collection of Mr. Victor Dan, of Manila.

Additional, non-typological specimens are in the collection of Mr. F. G. Dayrit of Manila (figured by DAYRIT, 1967, p. 4, fig. 4).

**Remarks:** The new species differs markedly from its congeners by its larger size, ornate ribbing, and coloring.

*Scalptia mercadoi* is perhaps closest in relationship to *S. textilis* (KIENER, 1841), and to *S. scalariformis* (LA-

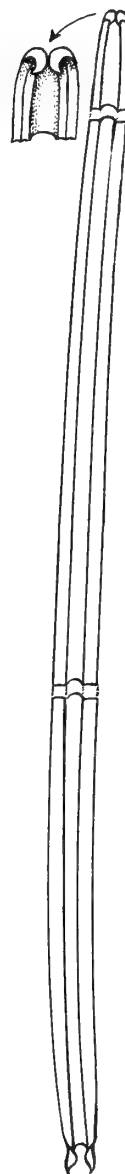


Figure 2

*Scalptia mercadoi* OLD, spec. nov.

Enlargement of radula (approximately  $\times 480$ )

Length about 3 mm, width  $2\mu$ . Drawing courtesy of Mr. Anthony D'Attilio, from a sketch by Mr. Masao Azuma

MARCK, 1822). KIENER's species also occurs in the Philippines, but it inhabits shallower water than does *S. mercadoi*. LAMARCK (1822) briefly described *Cancellaria scalariformis* without citing figures or localities. SOWERBY (1833) stated, "[Lamarck's] *C. scalariformis* is unknown to me." DESHAYES & MILNE-EDWARDS (1843) repeated Lamarck's description, citing figures of KIENER (1841). These figures seem to be referable to specimens in the American Museum which appear to be Lamarck's taxon.

Other figures and descriptions of related taxa which somewhat resemble the new species, are those of *Cancellaria funiculata* HINDS, 1844 and of *C. lyrata* ADAMS & REEVE, 1848 (non BROCCHI, 1814, nor BORSON, 1820). *Cancellaria funiculata* was described as having been taken in 7 fathoms, Gulf of Magdalena [Mexico]. The locality of *C. lyrata* was given as "China Seas," which REEVE (1856) and LÖBBECKE (1887) believed to be erroneous. REEVE, LÖBBECKE, and CROSSE (1861) considered *C. lyrata* of ADAMS & REEVE to be synonymous with *Cancellaria funiculata* HINDS. KEEN (1958) questioned the Panamic occurrence of *Trigonostoma funiculata* (HINDS), but this sentence has been deleted from the 1960 edition, probably due to the examination of material with reliable locality data from the Panamic marine province. The American Museum has 8 specimens taken in 30 fathoms, by the Templeton Crocker Expedition at Manzanillo, Mexico in 1938. These specimens appear to be typical specimens of Hind's *funiculata*.

In recent years, both of these specific taxa also have been applied to shells occurring in the western Pacific. KURODA & HABE (1952), however, queried the occurrence of *Trigonostoma funiculata* (HINDS) in Japanese waters. HABE (1961a) proposed the generic name *Nipponaphera* with *N. lyrata* (ADAMS & REEVE) as the type species. HABE (1961b, 1964) repeated the same figure (as in 1961a), but employed Hind's taxon, *N. funiculata*. OYAMA (1963) also figured a Japanese specimen under this name. Japanese shells which have been referred to *N. funiculata* (HINDS) are probably specimens of *N. iwaotakii* HABE, 1961, though HABE (1961b) cited sculp-

tural differences between his species and shells which had been identified as *N. funiculata* from Japanese waters.

The taxon *Cancellaria lyrata* also has been employed for a species from the Tertiary of Europe. BROCCHI, 1814, had described the fossil from the Piedmont district of Italy as *Voluta lyrata*. BORSON (1820) subsequently used the combination *Cancellaria lyrata* for Brocchi's species (*vide* SACCO, 1894). Most workers have placed Brocchi's *lyrata* in the genus (or subgenus) *Sveltia* JOUSSEAUME, 1887, although STRAUSZ (1966) recently referred the fossil species to the subgenus *Calcarata* JOUSSEAUME, 1887, which he placed in *Cancellaria* (*s. l.*).

In the present century, the taxon *Sveltia lyrata* (BROCCHI) also has been applied to a Recent species that is rather rarely trawled off western Africa. DAUTZENBERG & FISCHER (1906) cited a specimen from 628 m near Maio, Cape Verde; ADAM & KNUDSEN (1955) cited 4 examples from 145 m, 210 m, and 230 m off Cabinda; MARCHE-MARCHAD (1958) off Cape Verde, GRAHAM (1966) cited material from 170 - 200 fathoms, in the Gulf of Guinea; and BARNARD (1958, 1959) off South West Africa. BARNARD questioned the use of Brocchi's taxon for the Recent mollusk. It is unlikely that the Recent species and the Mio-Pliocene fossil from northern Italy and Central Europe are conspecific.

## ACKNOWLEDGMENTS

I wish to thank the following people for assistance of various kinds: Mr. and Mrs. Clifford Ames, Mr. Victor Dan, and Mr. Mario Mercado, of the Philippines; Mr. Masao Azuma of Nishinomiya, Japan; Dr. C. A. Fleming of Wellington, New Zealand; Mr. & Mrs. Crawford N. Cate of Los Angeles, California; Mr. Richard Petit of Ocean Drive Beach, South Carolina.

I am particularly indebted to my colleagues at the American Museum of Natural History, Dr. William K. Emerson, Mr. Anthony D'Attilio, and Mrs. Margaret Richards for various courtesies.

## Explanation of Plate 43

*Scalptia mercadoi* OLD, spec. nov.

Figure 1: Holotype (AMNH no. 138276); trawled in 175 fathoms, off Gasan, Marinduque Island, Philippines (x 2). c: Basal view of holotype (x 2)

Figure 2: Paratype "B" (Victor Dan collection); trawled in 120 fathoms, Tayabas Bay, Quezon, Philippines. (x 2)

Figure 3: Paratype "A" (Crawford and Jean Cate collection); Tayabas Bay, Quezon, Philippines. a: view of apex (approximately x 10); b and c (x 2)

Photographs courtesy of American Museum of Natural History



Figure 1 a



Figure 1 b



Figure 2 a



Figure 2 b



Figure 1 c



Figure 3 a

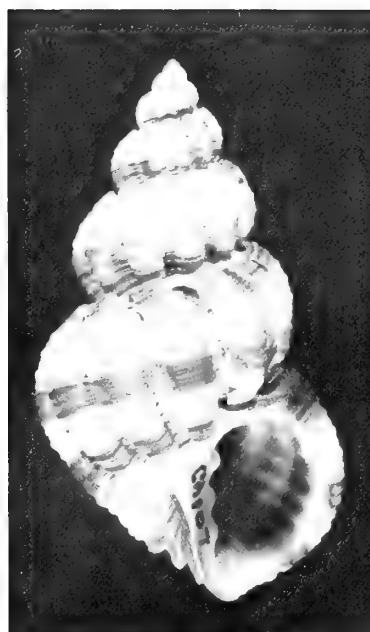


Figure 3 b



Figure 3 c



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# A Ctenostomatous Ectoproct Epizoic on the Chiton

## *Ischnochiton mertensii*

BY

EUGENE S. HELFMAN

Department of Zoology, University of California, Berkeley, California 94720

(2 Text figures)

DURING THE SUMMER of 1966 I collected 167 chitons of 18 species; collections were made both intertidally and subtidally in the region of Bodega Bay, Sonoma County, California. On three individuals of one species, *Ischnochiton mertensii* (MIDDENDORFF, 1846), stoloniferous ectoprocts of the species *Farella elongata* (VAN BENEDEN, 1845) were found attached to the ventral surface of the girdle, while all other chitons observed were free from any similar attachment. A review of the available literature has not revealed any descriptions of an ectoproct-amphincuran relationship of the nature discussed here.

OSBURN, 1963, described the habitat of *Farella elongata* as intertidal, where the species is said to form a dense, mat-like network of colonies on the substrate. O'DONOGHUE & O'DONOGHUE, 1923, found it on *Pinnixa* species, but failed to give any details. As found on *Ischnochiton mertensii*, the ectoproct colony consists of several 1.0 mm zooecia arising from one or a few elongated stolons. A stolon with its branching polypides may extend half the length of a 4.0 cm long chiton, giving off other stolons at various places along the girdle (Figure 1). The organ of attachment is the stolon, the polypides being free from the substrate.

The sites of attachment of the ectoprocts varied on the three chitons affected. The longest stolons and greatest number of polypides were found in the slight depression of the ventral girdle tissue bordering the pallial groove (Figure 2). Branches of these stolons and some individual polypides were located on the flat portion of the ventral girdle, while isolated polypides were found along the edge of the girdle on two of the three chitons. The approximate number of ectoprocts on each chiton was 100, 62, and 20. No individuals of *Farella elongata* were found on the dorsal surface of the chitons, nor were any other ectoprocts found on the ventral surfaces.

Several of the polypides that bordered the pallial cavity projected their tentacles into the chiton's incurrent groove

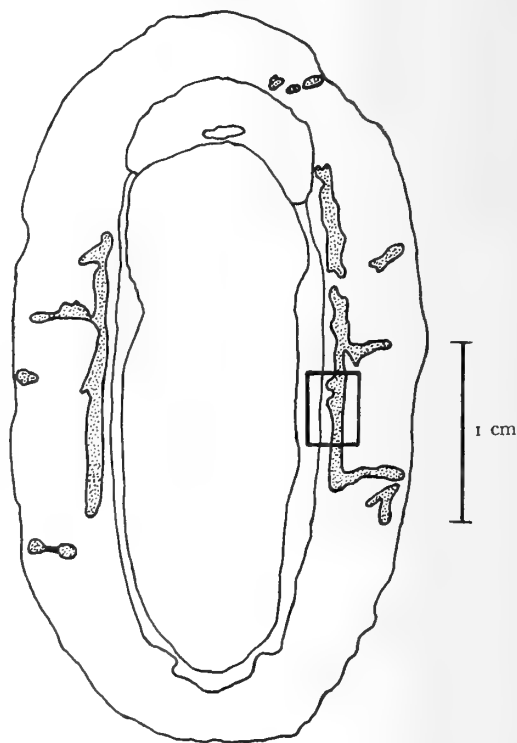


Figure 1

Ventral aspect of *Ischnochiton mertensii* (MIDDENDORFF, 1846). Stippled areas show the general configuration of approximately 100 attached ectoprocts of the species *Farella elongata* (VAN BENEDEN, 1845). From a photograph of the live animals  $\times 3$

and contacted the ctenidial leaflets. These ectoprocts filtered out and ingested particles flowing in the current of the mantle cavity. The tentacles in contact with the ctenidial leaflets projected outward from the ectoproct's

aperture like a cone, with cilia on the inward-directed surfaces of the 14 tentacles. The distal tips of the tentacles touched the ctenidial leaflets, and particles were seen to pass ventrally along the cilia of the leaflet, onto the ciliated inner surface of the tentacles and toward the mouth of the ectoproct, at which time the tentacles would be quickly retracted and the particles ingested or rejected.

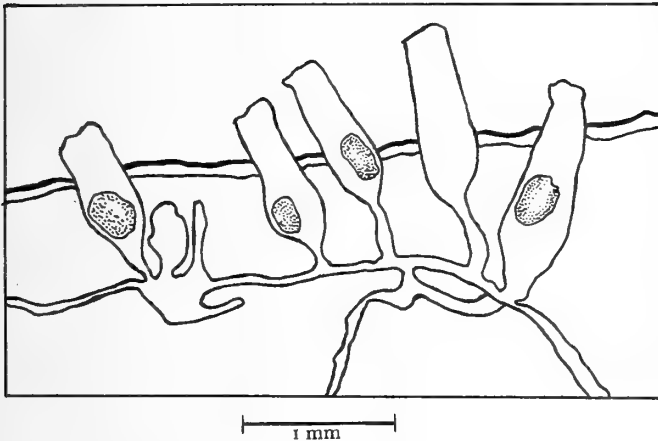


Figure 2

Enlargement of the inset in Figure 1

The zoecia of *Farella elongata*, with the apertures of the five polypides oriented toward the pallial cavity on the left side of the chiton. From a photograph of the live animals  $\times 25$

The literature revealed two instances of branchial cavity attachment by organisms living in a way similar to that of *Farella elongata*. OSBURN, 1953, reported that the ectoproct *Triticella elongata* had been found living in the gill chambers of the pinnotherid crab *Scleroplax granulata*. SOULE & SOULE, 1965, reported two species of loxosomatid entoprocts epizoic upon the gill filaments of a mantis shrimp from Southern California.

DALES, 1966, stated that many ectoprocts "may be found as epibionts on other animals, but the associations are not usually specific;" and ADEGOKE, 1967, reported

that two opposing schools of thought had developed, one regarding ectoproct-molluscan associations to be fortuitous, the other maintaining that ectoproct species are very specific in their choice of substrate. A statement on the possible specificity of the present association will have to await more extensive collection and observation.

## ACKNOWLEDGMENTS

I would like to thank Professor Cadet Hand of the Department of Zoology, University of California, Berkeley, and Professor Charles R. Stasek, Department of Biological Science, Florida State University, for their suggestions and criticisms. Professor John D. Soule of the Allan Hancock Foundation, University of Southern California, identified the ectoproct from slides prepared by Mr. Lloyd Austin of the Department of Zoology, University of California, Berkeley.

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## NOTES &amp; NEWS

New Record of *Conus ebraeus*  
in Costa Rica

BY

JOSEPH R. HOUBRICK

Department of Science and Mathematics  
Saint Leo College, Saint Leo, Florida 33574

*Conus ebraeus* LINNAEUS, 1758, an Indo-Pacific cone, is known to range in the eastern Pacific to Clipperton Island and also to the Galapagos Islands. KEEN (1958) and HANNA (1963) both stated that Mr. Ted Dranga found it living in Costa Rica. There seem to be no other published records of *C. ebraeus* from the Central American coast. On March 18, 1965 I collected two living specimens of *C. ebraeus* LINNAEUS under rocks in the intertidal zone one mile south of Playas del Coco, Guanacaste Province, Costa Rica. These specimens have been deposited in the Museum of Comparative Zoology, Harvard University.

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1958. Sea shells of tropical West America; marine mollusks from Lower California to Colombia. i-xi + 624 pp.; illus. Stanford, Calif. (Stanford Univ. Press)
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1963. West American mollusks of the genus *Conus*; II. Calif. Acad. Sci. Occ. Papers 35:1-103; pls 1-11 (28 Jan. 1963)

Spawning Notes, I.  
*Hexaplex erythrostomus*

BY

FAY HENRY WOLFSON

Associate Curator of Conchology  
San Diego Museum of Natural History, San Diego  
California 92115

(1 Text figure)

*Hexaplex erythrostomus* (SWAINSON, 1831) was encountered only once during intensive collecting (11 and 5 days, respectively) in June and July 1967 in Bahía de los Angeles, Baja California: on July 20, I came upon a

group of seven individuals in the process of depositing egg masses on rock substrates. Local residents inform me that this was the beginning of an annual spawning migration from the depths by this species. Two egg masses, each within a single mussel valve, were also found on the reef.

In September, specimens ranging from 1" to 4" were present throughout the bay, 4 egg masses, all deposited in mussel valves were found, and an individual was observed spawning on a small rock while two others were copulating beside it.

One irregularly shaped egg mass measured 100 mm by 70 mm by 40 mm (greatest dimensions) and consisted of approximately 400 curved, tongue-shaped capsules, the base of each attached in an irregular manner to one or two underlying capsules. A few short stalks cement the mass to the substrate. Individual capsules are roughly of the same size (see Figure 1), averaging 6 mm in length

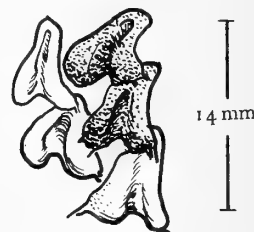


Figure 1

and 1 mm in breadth; average width is 6 mm at the base of the "tongue," 3 mm at the tip. The upper surface bears a groove with rounded edges, the lower is smooth and convex. The base color is creamy white, when fresh, but some capsules (generally those at the base of the mass) are tinged with varying amounts of pink, ranging from the shade characteristic of the species to magenta. The eggs exhibit the same range of pigmentation, which may be indicative of the degree of development. There are over 100 eggs per capsule.

The mass apparently serves as a symbiotic habitat: a 1 cm amphipod, an 8 mm *Hormomya* and several copepods were lodged between the capsules of the masses collected.

## A. M. U.

The thirty-third annual meeting of the American Malacological Union was held at Ottawa, Ontario, Canada July 31<sup>st</sup> to August 5<sup>th</sup>, 1967. It was the best attended meeting in AMU history as 163 persons listened to a record

number of papers and enjoyed such added features as an all day field trip to an Ottawa River site, a banquet as guests of the National Museum of Canada and a trip to Montreal and its famed Expo 67.

Officers elected to serve until July, 1968 are:

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The 1968 meeting will be held July 15 to 19 at Corpus Christi, Texas, at which time six Texas Shell Clubs will join ranks to act as official hosts to AMU members, their families and friends. Pacific Division members especially are urged to attend. Detailed notices will be mailed in April, 1968.

M. C. Teskey

## COAN Molluscan Collection at University of California, Davis

BY

JAMES W. VALENTINE

Department of Geology, University of California  
Davis, California 95616

A collection of marine Mollusca from the eastern Pacific Ocean, assembled over many years by Eugene V. Coan, has been acquired by the Department of Geology, University of California, Davis. It is desirable to call attention to the present location of this collection, for it contains specimens that form the basis of published records (however, the shells from Santa Barbara County recorded by COAN, 1964, are not included). At this writing the Coan material at Davis is being catalogued and will be available for consultation soon.

With the acquisition of the Coan collection the Department of Geology at Davis has embarked upon a long-range program of building and maintaining a permanent reference (research) collection of Recent and fossil invertebrates and protists. The collection will be continually expanded and lodged, under the care of a professional curator, in a geology building now being designed. Storage of type material and of special collections will be provided for. We welcome the use of the collection by students of the Invertebrata and Protista.

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COAN, EUGENE VICTOR

1964. The Mollusca of the Santa Barbara County area. *Part I.—Pelecypoda and Scaphopoda.* The Veliger 7(1): 29-33. (1 July 1964)

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## BOOKS, PERIODICALS, PAMPHLETS

### Cretaceous *Thyasira* from the Western Interior of North America

by ERLE G. KAUFFMAN. Smithsonian Miscellaneous Collections, Volume 152, No. 1, Smithsonian Publication 4695, pp. 1 to 159, plates 1 to 5, text figures 1 to 18, June 30, 1967.

This paper deals especially with species of *Thyasira* of Cretaceous age. Seven species and 10 subspecies from the western interior of North America. The geologic occurrences and relationships of these forms are described in detail.

Pages 12 to 49 contain much information concerning the anatomy, morphology, variation, ecology, biotic association and general biology of various living species of this genus. The author mentions that most of the living species of *Thyasira* occur in the deep inner or outer sublittoral and bathyal environments of cool to cold water, on a bottom of soft mud lacking coarse clastic material.

LGH

### Notes on *Hydrobia totteni*

by GEORGE M. DAVIS. "Venus", the Japanese Journal of Malacology, vol. 25, pp. 27 to 42, 6 text figures. June 1966.

The author points up the characters based on which this species is considered specifically different from its closely related European ally, *Hydrobia ventricosa*. The excellent illustrations accompanying the discussion deal mostly with the morphology of the eastern American species. What appears to be a complete synonymy accompanies the article.

RS

### Marwick's Illustrations of New Zealand Shells, with a checklist of New Zealand Cenozoic Mollusca

by C. A. FLEMING. New Zealand Department of Scientific and Industrial Research, Bulletin 173, pages 1 to 456, frontispiece (portrait), and 145 plates; December, 1966. R. E. Owen, government printer, Wellington, New Zealand. Price 45 shillings (\$4.50).

This fine handbook of the New Zealand Geological Survey was prepared in honor of John A. Marwick of that organization, on his seventy fifth birthday. The major divisions of the volume are: introduction; checklist of New Zealand Cenozoic mollusca; bibliography; plates with explanations, references, localities, geologic ages; and an index. The line drawings of shells illustrated by Marwick in various publications (but not including those originally published in half-tone) are republished, and in addition, a few drawings by others.

This very useful work, such as we have become accustomed to expect from Dr. Fleming, will be a great aid to all workers who have occasion to refer to the Cenozoic mollusks of New Zealand. The checklist, bibliography, the many illustrations (1753 figures), as well as an index to families, genera, and species, all combine to furnish not only a valuable handbook but also a suitable tribute to John A. Marwick.

LGH

### Van Nostrand's Standard Catalog of Shells

by J. L. WAGNER & R. TUCKER ABBOTT. D. Van Nostrand Co., Princeton, N. J., second edition, October 12, 1967. — \$5.95.

The content of the new edition of this work is basically as described in my review of the first edition (The Veliger, vol. 7, no. 4, p. 255, April 1, 1965); thus, all of my earlier critical comments still apply. Some new material has been added to the Catalog, such as a list of the Marginellidae, lists of selected genera in Tonnacea, Muriceacea, and Buccinacea, Neritacea, Tridacnacea, and a few others. The new catalog now runs to 303 pages. To the "Quick Lists" two new areas have been added — the British Isles and South Australia. Some of the inequities in suggested values in these lists have been smoothed: I was relieved to find that the rarer abalones now are valued higher than commoner ones and that *Haloconcha reflexa*, an Arctic lacunid not yet in the Stanford collection, has gone up from 12 cents to 80 cents. On the other hand, *Mysella pedroana*, a very ordinary-looking small commensal clam, remains at 3 dollars, with or without data. *Hyalina californica* in the "Quick List" is valued at

4 cents (3 cents if dataless); in the Check List the name is cited as a synonym of *Volvarina taeniolata* and the value cited as 15 cents (10 cents without data).

The World Size Records now form a separate section, with a list running to eight pages of presumed records. Although not stated in the explanation of the list, the 1950-1959 records were culled from lists in the Minutes of the Conchological Club of Southern California. The implication is, rather, that these records were submitted especially to the present editors of this compilation. It is disconcerting, therefore, to find "A. M. Keen" listed as owner of a *Clinocardium* specimen that actually is and has been for the last twenty years or more in the Stanford University collection. This was made clear at the time the record was submitted, in 1950, to the Conchological Club editor. Others of the "owners" in the 1950 records are no longer living. This column in the list, therefore, should be differently captioned.

As indicated in the previous review, it is probable that the most useful part of this catalog will prove to be the check lists of genera and families, even though the total is yet far from being complete and comprises only some of the more showy molluscan groups.

MK

### Chitons and Gastropods (Haliotidae through Acanthinae) from the Western Pacific Islands

by HARRY S. LADD. U. S. Geological Survey Professional Paper 531, 98 pp., 16 pls., 1966

About 200 molluscan species and subspecies are discussed in this initial report on late Tertiary and Quaternary horizons in seven Island groups of the western Pacific. Three new subgenera are proposed: *Vitiastrea*, subgenus of *Astrea* (family Turbinidae); *Subditotectarius*, subgenus of *Tectarius* (family Littorinidae) — both from the lower Miocene; and *Ailinzebina*, subgenus of *Zebina* (family Rissoidae), living, Marshall Islands. Some 75 species and subspecies are described as new and illustrated by photographs of exceptional quality.

The introduction has a useful review of known records of Cenozoic fossil mollusks from this region, an area in which relatively little collecting has been done. Material is yet too scanty to justify generalizations on migration or dispersal routes, but the occurrence of a genus hitherto known only in southern Baja California — *Haplocochlias* — and another — *Arene* — that is largely confined to tropical America, suggests that movement from east to west may at times have been possible.

MK

**Pliocene Fossils from Rancho El Refugio,  
Baja California, and Cerralvo Island, Mexico**

by LEO GEORGE HERTLEIN. Proc. Calif. Acad. Sci. vol. 30, no. 14, pp. 265 to 284, figs. 1 to 17. 30 Nov. 1966

Two new subspecies, one of *Ostrea* and one of *Chlamys*, are described. A summary of earlier work on the fossil fauna of the two localities is given. In analyzing the lists of species recorded, the author finds that the Recent fauna in the adjacent waters is very similar.

RS

**Dimensions and Shapes of Larvae  
of some Marine Bivalve Mollusks**

by VICTOR L. LOOSANOFF, HARRY C. DAVIS & PAUL E. CHANLEY. Malacologia, vol. 4, no. 2, pp. 351 to 435; 61 text figs. (half-tones and graphs).

Based on recent developments in methods of rearing bivalve mollusk larvae, developed by Dr. Loosanoff and his co-workers, the authors report on the observations on

20 different species. Larvae were grown past metamorphosis from eggs or recently released larvae of known parents. Data concerning each of the 20 species studied are given. A number of problems in identification, particularly of closely related forms are discussed. Helpful suggestions for improved methods of identification are given.

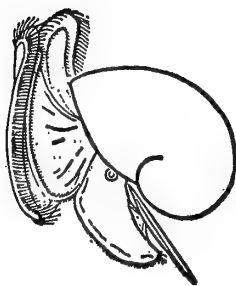
RS

**Der Status zweier von Peter Merian beschriebener  
Arten von Gastropoden**

by PETER JUNG. Verhandl. Basler Naturforsch. Gesellsch., vol. 77, pp. 76 to 81; 8 text figs. June 30, 1966.

Two fossil species of Gastropods, obtained in the year 1843 from Jamaica and Antigua respectively, were described by MERIAN in 1844 as *Terebellum procerum* and *Scalaria melanoidea*. The latter taxon was a *nomen dubium*, while the former is apparently a valid species. In 1914, BROWN & PILSBRY described *Hemisinus antiguensis*, using the material that Merian had had.

RS



**THE VELIGER** is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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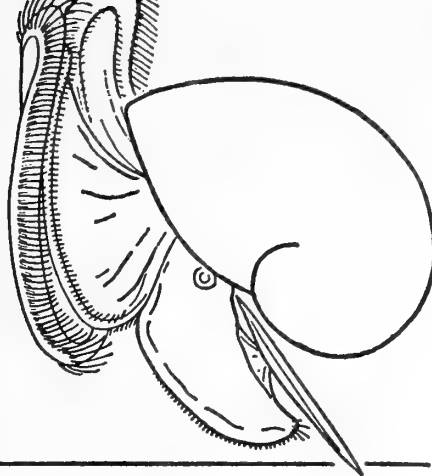
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Note: The various taxa above species are indicated by the use of different type styles as shown by the following examples, and by increasing indentation.

ORDER, Suborder, DIVISION, Subdivision, SECTION,  
 SUPERFAMILY, FAMILY, Subfamily, Genus, (Subgenus)  
*New Taxa*

## Reproduction in *Olivella biplicata*

BY

D. CRAIG EDWARDS

Department of Zoology, University of Chicago

Department of Oceanography, Scripps Institution of Oceanography<sup>1</sup>

(Plate 44; 3 Text figures)

IN CONJUNCTION with more general studies of *Olivella biplicata* (SOWERBY, 1825) considerable information has been obtained on its reproduction. These observations cover aspects of sexuality, the courtship and mating behavior, including documentation of a nonrandom mating pattern, evidence of year-round mating and settlement, a fecundity count, and the first description of the egg capsule, larva, and form of early development. Field work was done at various sites on the Oregon and California coasts; laboratory investigations were done at the Oregon Institute of Marine Biology, Charleston, Oregon, and at Scripps Institution of Oceanography, La Jolla, California.

### GONOCHORISM

*Olivella biplicata* is dioecious with internal fertilization, but sexual dimorphism is not conspicuous. Sex is most easily determined from the positions of individuals in courting pairs. Alternatively presence or absence of a penis, shape of the ventral pedal gland, gonad color, or form of the genital tracts may be used. Although presence of a penis is decisive, absence may indicate either a female or a male that has lost sex characters owing to trematode infection, in which case a small, easily overlooked rudiment may remain. Females possess an inconspicuous, cup-shaped pedal gland for molding and attaching egg capsules, whereas males have a longitudinal, probably glandular (see later) slit at this site. The mature testis is orangeish, the ovary yellowish, but the difference is slight and is lacking in immature or parasitized animals. The anatomy of the genital tracts is given in MARCUS & MARCUS (1959a) and ZELL (1955).

Unlike most prosobranchs (COMFORT, 1957; FRETTER & GRAHAM, 1964; GALTISOFF, 1961; ABBOTT, 1954; ROBERTSON, 1959), male *Olivella biplicata* grow faster

(FRANK & EDWARDS, unpubl. data) and are larger than females. (Size data hereinafter are shell lengths from the siphonal canal to the apex.) The sexual size dimorphism was demonstrated by measuring and sexing the mature snails taken in total-count transect sampling across *Olivella*-occupied beaches (Table 1). In addition, in experiments regarding size as a treatment, randomly selected "Large" snails (22.0-25.0 mm) were nearly all males, whereas most of the "Medium" snails (17.0 to 20.0 mm) were females. Finally, males taken in courting pairs were significantly larger than their female partners (Table 2; Figures 1 and 2). Thus shell size and the spacing of growth lines provide weak sex indicators: lines are close together on slow-growing female shells, which rarely exceed 23 mm, but further apart on male shells, which are often large (up to 30 mm).

Table 1

Mean lengths ( $\bar{X}$ ), standard deviations (SD), and numbers (N) of mature snails of each sex taken in transect sampling at two beach sites on the Oregon coast in 1964.

Site	Males			Females			P
	$\bar{X}$ (mm)	SD	N	$\bar{X}$ (mm)	SD	N	(t-test)
Yaquina Bay	19.55	1.57	67	18.80	1.15	45	0.01
Coos Bay	19.84	2.67	52	18.45	1.71	58	0.01

Both STOHLER (1959-1960) and I (several sets of measurements) find that, in contrast to some gastropods (FRETTER & GRAHAM, 1964), female *Olivella biplicata* shells are no more tumid than male ones.

Among mollusks generally, and including *Olivella verreauxii* (DUCLOS, 1857) (MARCUS & MARCUS, 1959a and b), females tend to be more numerous than males. As the disparity is lacking in young animals and increases with age, it is attributed to earlier death in males (FRETTER & GRAHAM, 1964). COMFORT (1957) also reports

<sup>1</sup> Present address: Department of Zoology, University of Massachusetts, Amherst, Massachusetts 01002.

greater longevity for females. These findings could, however, be due to mistaken sex identifications with parasitized animals, wrongly equating age with size, or sampling bias favoring capture of larger individuals. Sex ratios for *O. biplicata* can be read from the N columns in Table 1. The ratio was approximately 1:1 for both whole populations and by beach levels within them. Of the 52 males (vs. 58 females) taken at Coos Bay less than half (23) had a functional penis – often it was absent. For the effective sex ratio to be unity, the probability of sexual impairment from parasitic infection would have to be the same for both sexes. At Yaquina Bay, where design forbade dissections, 67 males, 45 females, and 16 “unknowns” were taken. Most “unknowns” would be females, since their sex characters are hard to detect and positive identifications were required.

*Olivella biplicata* of both sexes mature sexually at about the 16 mm size: these are the smallest snails taken in numbers in courting pairs (Figures 1 and 2). Since 16 mm probably represents about 1 year's growth and *O. biplicata*'s longevity likely exceeds 10 years (FRANK & EDWARDS, unpubl. data; STOHLER, 1962, and personal communication), about 10% or less of the life span is passed in immaturity. Prosobranchs generally exhibit no genetically set post-reproductive period, though heavy trematode infections can have the same effect.

## MATING BEHAVIOR

Courtship in *Olivella biplicata* is initiated by the male's extending his propodium and grasping the female's shell at or near its apex. A tandem, courting pair results, with the female in front, the male behind (Plate 44). While joined, the pair alternately moves about and sits quietly; the female may feed. A characteristic activity of courting snails is a forward-and-back rocking of the body on the large foot. This motion is more common in females, who initiate it, than in males, but at times the partners rock together in unison. Whether this activity is a necessary prelude to copulation is not known, but ZELL (1955) believes it is one step in a reciprocal reaction chain like those demonstrated in the courting sequences of many animals (TINBERGEN, 1953).

Although MARCUS & MARCUS (1959 b) found no evidence for it in *Olivella verreauxii*, the bond between courting *O. biplicata* is a sticky mucus, strands of which adhere to the shell apices of females from pairs. This adhesive is apparently secreted by the male's pedal gland, which may, in courting males, be filled or covered with thick mucus. This connective can support the weight of the male when the female is lifted from the substrate,

and the coupling is maintained when a pair is rolled about by beach surf. In a shifting medium like sand an attachment between courting individuals likely helps ensure fertilization (see PEARSE *et al.*, 1942).

Pairings may persist for a long time: one couple was joined continuously for at least 31 hours, and another paired repeatedly for 3 days. During courtship the male extends his penis along the right side of the female shell and, when successful (many attempts fail; males are very sensitive to disturbances at this vulnerable stage), into her mantle cavity. Males have sometimes advanced on the right side of the females' shells by this stage. During intromission, which on several occasions lasted about 10 minutes, the two snails are firmly locked together. Copulation may occur repeatedly between a single pair, or individuals may mate with several partners in a few days time.

Mate-finding in *Olivella biplicata* seems to be based on males' reactions to short-lived chemicals left in female mucus trails, contact chemosensory responses, and possibly tactile cues, but not on distance chemoreception. Although these snails often travel for a distance in each others' sand trails (probably a tactile response), males are unable to use direct trail following to locate distant females. But a male coming upon a very fresh track of a sexually-ready female (usually less than 15 cm away) turns into the track, accelerates, makes contact, and attempts to pair. Evidence for a chemical stimulus in female mucus trails is furnished by occasional observations of triplets consisting of a regular courting pair with a second male behind the first, all linked in tandem. No pairings of males alone were observed. (One new male bit the courting male, who turned aside, the former taking the female!) Males who paired repeatedly, however, showed surprisingly little ability to relocate their partner when pairing was interrupted: although lying just behind the female, they often moved off in an inappropriate direction, sometimes attempting unsuccessfully to attach to another nearby snail. Once (San Diego Flood Control Channel; 3 August 1966) a male *Olivella baetica* CARPENTER, 1864, was found courting a female *O. biplicata*, suggesting that initially sex may be more readily discriminated than species. During courtship, males often curl the lateral edges of their propodia anteriorly under the females, contacting the latter's metapodia; females sometimes extend their proboscides to their shell apices and the male propodia and occasionally bite the latter, terminating courtship. Females may also curl the posterior edge of the metapodium dorsally, preventing male coupling – though one male bit this barrier and later formed a pair. These

contacts would permit contact chemosensory responses and further discrimination of partners.

Distance chemoreception in mate-finding was tested on a large (91 cm by 290 cm) outdoor water table fitted with a median longitudinal divider (115 cm) at the water inlet end. On one side sea water passed through an enclosure of females from pairs and on the other through an empty enclosure. Males from pairs were released at the downstream end of the table, but showed no tendency to move preferentially toward the females. The high densities in natural *Olivella biplicata* populations and the snails' considerable mobility should produce frequent contacts between sexually ready individuals without special means of mate-finding at a distance being required.

On the gently sloping, protected sand beaches where *Olivella biplicata* usually lives, this snail develops a size class distribution with large animals higher on the shore, smaller lower (EDWARDS, 1965). The resulting graded separation of reproductives and immatures should further aid mate-finding efficiency.

Measurements of individuals in courting pairs showed that 1) males were significantly larger than their female partners, as expected from the sex difference in growth rate (Table 2 and see above) and 2) mating is non-random, larger males pairing with larger females, smaller males with smaller females (Figures 1 and 2). The best evidence for the mating pattern is given in Figure 1, since at the Charleston lagoon the lengths of 210 nearest

neighbors of 97 pairs were found to be independent of the courting females' sizes: the regression slope  $b=0.067$  was not statistically significant (data furnished by Peter W. Frank). Apparently lagoon channel shifts and currents do not permit a size class distribution to be developed at this site. Inspection of Figure 1 suggests large males mate less selectively than small males, which court only smaller females. Figure 2, on the other hand, presents data from sites where segregation of *Olivella biplicata* by size category has been demonstrated (Yaquina Bay, Coos Bay, and Duxbury Reef [EDWARDS, 1965]) or indicated (Monterey Harbor [REYNOLDS, 1948] and San Diego Flood Control Channel [F. Wolfson, cited in STOHLER, 1959-1960]). Although the relationship between male and female sizes is not statistically significant for any of these small samples, the trend is evident: the regression line for the grouped data ( $N=82$ ) is

$$Y = 13.223 + 0.444 X,$$

slope  $b$  statistically significant at the 0.01 level. The steeper slope for these samples, compared to the Charleston lagoon value ( $b=0.350$ ), may be due to the size class distribution. Also at Duxbury Reef, where only larger animals were taken in pairs (Figure 2), the nonselectivity of large males is clear (nonsignificant slope  $b=-0.343$ ).

Although differences in activity cycles — large snails are active at night, whereas small ones may be active in the light (EDWARDS, 1965) — could account for non-random mating, the nonselectivity of large males sug-

Table 2

Differences in lengths of males and females taken in courting pairs  
at six sites on the Oregon and California coasts.

Site	Date	Pairs (N)	Pairs with $\sigma \sigma > \varphi \varphi$	Mean Difference $\sigma - \varphi$ (mm)	SD	p <sup>a</sup>
Yaquina Bay (Tide pool stream)	June-July 1964	18	17	2.88	2.53	0.001
Coos Bay (Charleston lagoon)	July-Aug. 1963	197	150	1.85	2.53	<0.001
Coos Bay (Beach)	June-July 1964	20	15	1.94	2.77	0.01
Duxbury Reef <sup>b</sup>	Oct.-Jan. 1964-65	22	18	2.51	2.43	0.001
Monterey Harbor <sup>c</sup>	Nov. 1964	6	3	0.22	1.96	0.80
San Diego Flood Control Channel	Oct.-June 1965-66	16	14	1.91	2.31	0.01

<sup>a</sup> tested by paired comparison t-test

<sup>b</sup> STOHLER (1959, 1960) found females larger than males in all of 11 pairs taken here. No explanation for the disagreement is a-

vailable except for sampling error

<sup>c</sup> no large snails were taken in pairs here (cf. Text figure 2), possibly owing to trematode infections

gests another explanation. Since in mating a male must extend his penis most of the length of the female's shell and into the mantle cavity, probably small males simply

mating effectiveness. Since pairing data came from courting snails, many of whom had likely not yet copulated, apparently either or both sexes can recognize and select, probably by chemosensory means (see above), partners of suitable sizes before actual mating attempts.

### YEAR-ROUND MATING AND SETTLEMENT

Three lines of evidence indicate that *Olivella biplicata* both breeds and spawns all year. (1) STOHLER (1959-1960) and I have both observed courting pairs in every month. Numbers mating at a given time seem to be due more to as yet undetermined local, short-term conditions than to annual changes: large numbers mate in every season, though on successive spring tide series pairs may be abundant or scarce. (A complicating factor is that pairs are easier to find in dim light and quiet water.) (2) The smallest, youngest snails taken by sieving (4 to

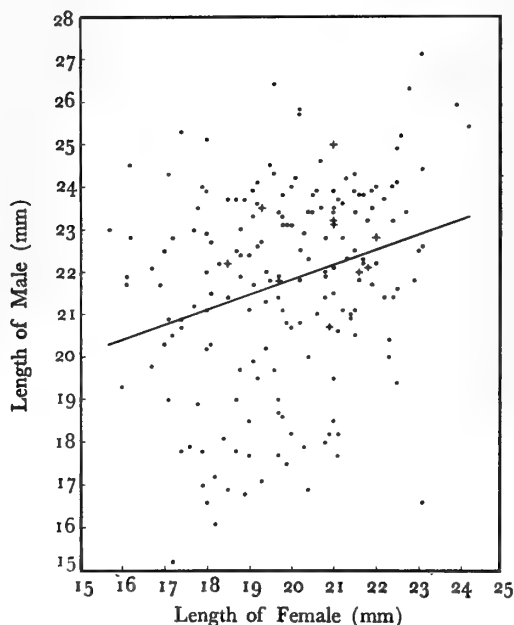


Figure 1

The relationship between lengths of males and females taken in 197 courting pairs at the tidal lagoon, Charleston, Oregon, July to August 1963. Single pairs are indicated by a solid circle, two pairs by a circle with a cross through it. The regression line, fitted by the least squares method, is  $Y = 14.815 + 0.350X$ . Slope  $b$  is statistically significant at the 0.001 level. (Data collected by Peter W. Frank)

cannot accommodate larger females. A suggestion that small males are at a disadvantage in courting comes from a comparison between mean sizes of mature animals taken in total count sampling and those from courting pairs: on the Coos Bay beach, the only site for which such data are available, courting males were somewhat larger than mature males over-all (20.78 mm vs. 19.84 mm;  $P = 0.10$ ), whereas female sizes were very similar (18.84 mm vs. 18.45 mm;  $P = 0.50$ ). Another test would be a comparison of the mating success of large females isolated with large vs. small males. If small males are inferior mating partners, the size class distribution of *Olivella biplicata* would promote efficient pairing both by separating mature snails from immatures and by placing large matures with large, small with small. The more rapid growth of males may also be related to their

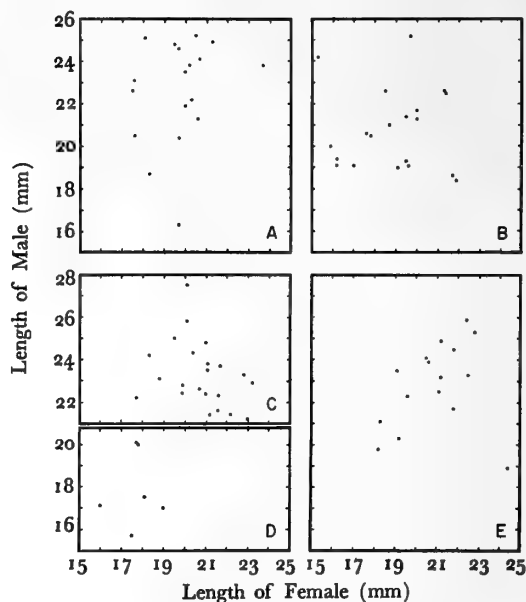


Figure 2

The relationship between lengths of males and females taken in courting pairs at five sites on the Oregon and California coasts.

- (A) Yaquina Bay (44° 37' N Latitude)
  - (B) Coos Bay, beach (43° 21' N Latitude)
  - (C) Duxbury Reef (37° 54' N Latitude)
  - (D) Monterey Harbor (36° 36' N Latitude)
  - (E) San Diego Flood Control Channel (32° 45' N Latitude)
- Sampling dates are given in Table 2



A courting pair of *Olivella biplicata* with the female in front  
and the male following



5 mm) entered the Coos Bay beach population throughout the year and occurred at every locality on every sampling date. (3) Size frequency distributions for populations showed no breaks that would indicate year classes. Because small animals do not cease growing in winter as mature snails do (EDWARDS, unpubl.), the lack

of year class modes cannot be accounted for on the basis of mating and spawning only occurring during periods of growth for all snails. Whether individuals, in contrast to populations, exhibit reproductive cycles is not known.

Using the occurrence of mating pairs or of very small animals at different times and places, GIFFORD & GIFFORD (1942, 1944, 1948) proposed a complicated series of mating seasons for *Olivella biplicata*. Their data equally well support year-round reproduction.

Year-round reproduction occurs in a number of marine gastropods (MOORE, 1938; RICKETTS & CALVIN, 1962; THORSON, 1950). In *Olivella biplicata* continuous breeding may be related to the genus' neotropical origins, there being some evidence that tropical forms enjoy longer breeding seasons than temperate ones (THORSON, 1950). However, *O. mutica* (SAY, 1822) in Florida apparently spawns for only about one month in spring (PAINE, 1962), and *O. fulgurata*'s (A. ADAMS & REEVE) spawning season in Japan is May to July (HABE, 1960).

Unless having new young enter the population all year is crucial for *Olivella biplicata*'s success, the factor thought to limit northward ranges of species, and hence faunal provinces, viz. the continuous period that sea temperatures meet requirements for reproduction and early growth (HALL, 1964), does not seem applicable here. Yet *O. biplicata*'s species range – Magdalena Bay, Baja California, Mexico (25° N Lat.) to lower Vancouver Island (49° N Lat.) (KEEN, 1937) – closely fits the limits of the Oregonian plus the Californian shallow water, marine faunal provinces (KEEN, 1958; HALL, 1964)<sup>2</sup>.

#### EGG CAPSULE, FECUNDITY AND TYPE OF EARLY DEVELOPMENT

*Olivella biplicata*'s egg cases and form of development were found by collecting courting females in the San Diego Flood Control Channel and maintaining them at Scripps Institution of Oceanography in aquaria provided with running sea water (14° to 15° C), a sand substrate, and possible ovipositing sites. Egg capsules were subsequently found on various bivalve shells, empty *O. biplicata* shells, glass slides, and glass and plastic dishes, but not on the mother shells as reported for Japanese species (HABE, 1960; HORIKOSHI, unpubl.). As in *O. mutica*, *O. pusilla* and *O. verreauxii*, empty shells are likely the substrate used by *O. biplicata* in nature. Capsules are attached separately and preferentially in depressions or grooves (c. g. on *Donax*); their dispersion pattern on

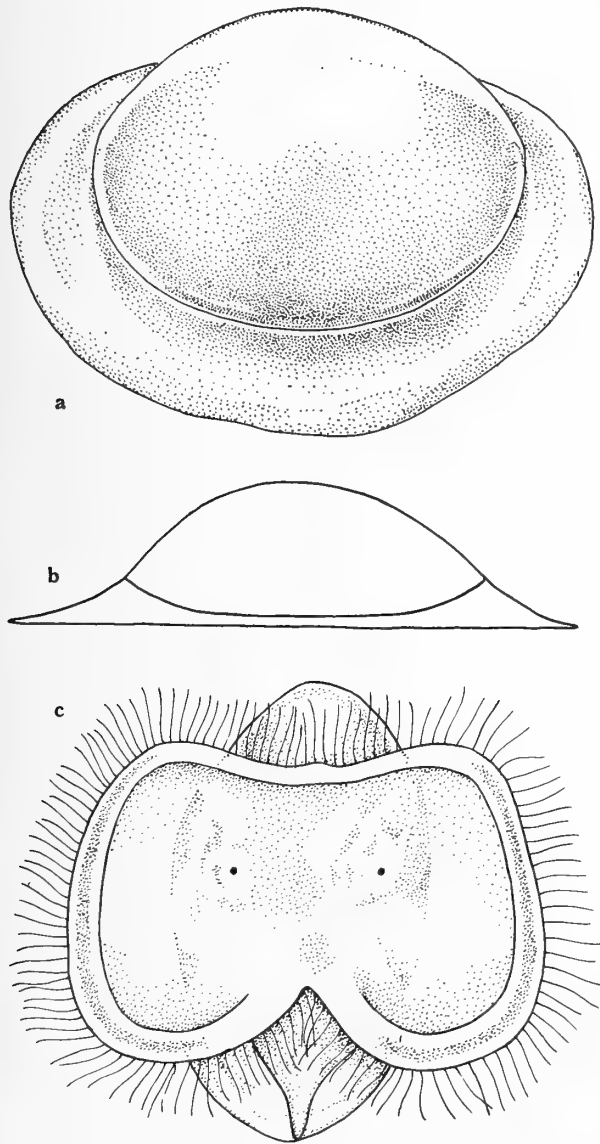


Figure 3

(A) The egg capsule of *Olivella biplicata*; three quarters view from above. (B) The same; diagrammatic cross section. (C) The veliger larva of *Olivella biplicata* shortly after hatching. These sketches of semi-transparent materials are not accurate in details.

(Drawings by Susan Ahrend)

<sup>2</sup> I. McT. Cowan (1964, personal communication) has, however, found empty shells of *Olivella biplicata* as far north as Queen Charlotte Island.

shells is markedly contagious, and on a smooth surface several may be placed contiguously.

The egg capsule (Figures 3a and 3b) consists of a dome-shaped cap with an indistinct median suture (not shown in the Figures) above a broader, slightly irregular base. Capsules are small (0.5 mm basal diameter; 0.3 mm lumen diameter), transparent, and unsculptured. A fission line borders the convex cap, which often comes free of the base at hatching. The capsule appears very similar to that figured for *Olivella fulgurata* from Japan (AMIO, 1963), but differs slightly from that of *O. verreauxii* from Brazil (MARCUS & MARCUS, 1959b), whose cap bears sculptured ridges, and considerably from those of *O. mutica* (PAINE, 1962) and *O. pusilla* (MARRAT, 1871) (PERRY & SCHWENGEL, 1955) from Florida, whose caps are more apical with a ridged border.

Although early development was not studied, *Olivella biplicata* would be good material for such work. Each transparent egg capsule contains one clearly visible white egg or embryo without "nurse eggs." Cleavage and larval stages are distinctly observable. The snails will oviposit on glass slides, and the time of spawning can be known precisely by exposing clean slides to mated females for short time intervals. Finally, year-round reproduction means eggs and larvae would be available in large numbers all year.

Numbers for eggs laid in capsules are generally modest compared to those broadcast into the sea. *Olivella* further provides for its young by placing them one to a capsule. To determine fecundity, courting females from the field were placed in separate clear plastic dishes provided with screen tops and running sea water (14° to 15° C). The containers were periodically examined for capsules, the females being transferred to clean dishes. One effort was successful. By total-count a 20.6 mm female deposited 4236 egg capsules in 46.8 days (June 22 to August 8, 1966); mean per day rate was 90.5 (range 60.6 - 171.4 for 3 censuses). This is a minimum estimate, since spawning may have ceased due to depletion of the gonad, decline in the female's vigor under artificial conditions (occasionally algal food was supplied), or lack of opportunity for repeated mating. The female may also have mated and spawned before capture. This count lies among previously reported values for capsule-spawning snails (PELSENEER, 1935). Size specific fecundity data would be valuable, as they might indicate the adaptive value of large size, slow growth, and long life in *O. biplicata* (cf. McLAREN, 1966).

Development time in the capsule was highly variable. Many young hatched by day 10, but others were still alive in their capsules after 28 days. All capsules were kept in 14° to 15° C circulating sea water, but the late-

hatching animals were subjected to occasional warming during microscope observations.

The young emerge as veligers (Figure 3c). The shell is nearly transparent and unsculptured; it is a barely skewed helix of ca.  $1\frac{1}{3}$  whorls and a maximum diameter of 0.2 - 0.3 mm. The large, bilobate velum has a light brown band of pigment near its borders and bears eye spots on slight prominences anteriorly. The body is nearly colorless, and internal organs, especially the visibly beating heart, are easily seen. The operculum is clear and scalelike.

The veligers are apparently nonpelagic. Rather they swim, anterior (eye spots) end down, at the bottom of their containers, opening and closing their velum lobes against the substrate. Occasionally they swim in a tight vertical loop, but return quickly to the bottom. The larvae appear to be examining the substrate. When clean sand was added to a dish, the animal opened and closed its velum around several grains, then swam on. Possibly these larvae never join the plankton; but, perhaps responding negatively to light and positively to gravity (several tests proved inconclusive), swim at the bottom until suitable cues for metamorphosis — presumably ones associated with lower shore situations — are detected. Balanced sex ratios across beach levels show females do not move down shore to spawn. The larval behavior would explain how the young, hatching higher on the shore where adults live, are able to cross wide expanses of beach and reach the lower shore levels where physiological stresses are within their ranges of tolerance (EDWARDS, 1965).

No larvae metamorphosed — or developed appreciably — when maintained in bare glass or plastic dishes, or in ones provided with sand. Isolated individuals died after 3 - 4 days. Presumably stimuli required for metamorphosis were missing from the laboratory set-up. Aggregations of very small snails occur on the shore, suggesting either that settlement is stimulated by irregular features of the environment or presence of settled young, or that metamorphosed young show strong positive responses to one another.

Since close relatives of *Olivella biplicata* from warmer water exhibit either direct development — *O. fulgurata* (AMIO, 1963), *O. spreta* GOULD, 1860 (HORIKOSHI, unpubl.), *O. mutica* (PAINE, 1962), and *Ancilla* sp. (NATARAJAN, 1957) — or a short, nonpelagic larval life — *O. verreauxii* (MARCUS & MARCUS, 1959b) — *O. biplicata* would have been expected to show direct development in cool West Coast waters (THORSON, 1950). Long breeding seasons are also often linked to direct development (THORSON, *op. cit.*). Yet the mixed occurrence, even within genera, of species with free-swimming veligers and others with direct development is well-known

among Prosobranchs (THORSON, *op. cit.*). A larval stage in the life history of *O. baplicata* appears to be an adaptation to the particular ecology of this species; it provides young an opportunity to attain suitable beach levels in a species exhibiting a marked segregation by size class.

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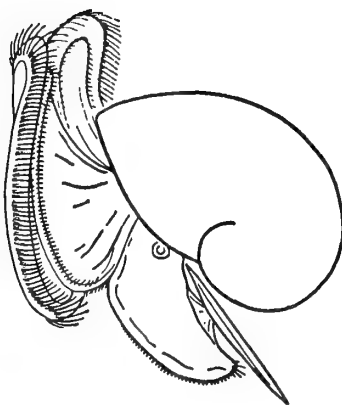
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# The Functional Morphology of *Lyonsia californica* CONRAD, 1837

(Bivalvia)

BY

WALTER NARCHI

Faculdade de Filosofia, Ciências e Letras Universidade de São Paulo, São Paulo, Brasil

(7 Text figures)

## INTRODUCTION

THE FAMILY LYONIIDAE comprises 3 genera: *Lyonsia*, *Mytilimeria* and *Entodesma* (ABBOTT, 1954, p. 468). The last is considered by THIELE (1963, p. 936) as a subgenus of *Lyonsia*. Species of *Lyonsia* are widely distributed in the northern hemisphere including the west coast of Europe and the Atlantic and Pacific coasts of North America.

*Lyonsia californica* CONRAD, 1837, occurs on the Pacific coast of North America from Puget Sound to Lower California (ABBOTT, 1954, p. 468). According to KEEN (1937, p. 21) it ranges from 24° to 56° North Latitude. Isolated references to this species were found in the papers of ATKINS (1937), KELLOGG (1915) and YONGE (1952), but there is no special research dealing with all aspects of the functional morphology of this species.

This paper is concerned with observations on the structure, ciliary currents of feeding and digestion, and other functional adaptations of *Lyonsia californica*. The animals were collected at Lawson's Flat and White Gulch in Tomales Bay, Marin County, California; the observations on live specimens were made at Pacific Marine Station, Dillon Beach, California.

## SHELL

The shell is about 3 times as long as it is broad and moderately obese in the anterior part where the shell valves are rounded, while the posterior end is laterally compressed. It is thin, fragile and almost transparent. The umbo is situated approximately one-third from the anterior end; the beak area is swollen. The shell is made largely of nacreous material and fractures easily. BOGGILD (1930, p. 291) noted that the shell valves consisted of a nacreous substance between two layers of fine prismatic structure.

The valves are covered by a thick layer of periostracum which covers the margin of the shell; weak, radial, dark lines run through the periostracum. Dorsally the two shell valves are joined along their entire length by periostracum; it covers the base of the siphons and the ventral surface of the fused mantle edges. This feature is considered as primitive by YONGE (1952, p. 446). In the living animal sand grains are found attached everywhere on the shell but adhere more firmly at the base of the siphons and to the ventral periostracum as in *Entodesma saxicola* BAIRD, 1863 (YONGE, 1952, p. 440). The dense accumulation of sand grains around the base of the siphons fills the posterior gape when the siphons are withdrawn.

There is a lithodesma under the hinge attached to the ligament which is very similar to that of *Entodesma saxicola* (YONGE, 1952, p. 446).

The margins of both valves are poorly calcified in the siphonal region as in *Pandora inaequalis* (LINNAEUS, 1758) (ALLEN, 1954, p. 474). The valves are slightly inaequivalve. When closed, the periostracum of the free margin of the left valve folds over and fits against the outer marginal region of the right valve.

The shell of the largest animal encountered in this study measured 38 mm in length, 16 mm in height and 12 mm in width.

## MANTLE

The mantle edges and periostracal grooves are fused ventrally (Figure 1, mef). There is a pedal gape (pg) and a smaller pallial aperture (a<sub>1</sub>), which opens about 5 mm from the base of the inhalant siphon (in). The fourth aperture in *Lutraria* and *Thracia* lies closer to the inhalant siphon than in *Lyonsia californica* and in *Entodesma saxicola* (ATKINS, 1937, p. 444). According to KELLOGG's figures of *E. saxicola* and *Mytilimeria nuttallii*

CONRAD, 1837 (1915, p. 654; figs. 22, 26, 27, 28) the fourth aperture of the mantle is just posterior to the region in which the rejecta brought by the mantle currents collect. While KELLOGG (*op. cit.*, p. 656) did not note the significance of this opening, YONGE (1952, p. 447) thought that it was a purely structural feature, possibly a result of the manner in which the mantle edges fuse during development.

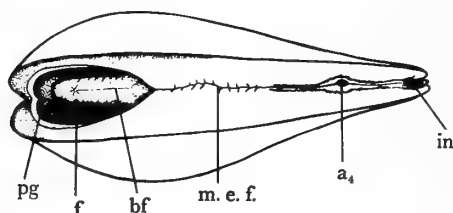


Figure 1

*Lyonsia californica* CONRAD

ventral aspect of the animal, showing the pedal gape and foot with byssal groove and the fourth aperture

a<sub>4</sub> - 4<sup>th</sup> aperture      bf - byssus fold      f - foot  
in - inhalant siphon      mef - mantle edges fused  
pg - pedal gape

On both sides of the fourth aperture fusion is complete. The muscles cross the ventral region from one lobe to the other. In *Ensis siliqua* and *E. arcuatus* actual tissue fusion occurs only posteriorly to the fourth aperture (ATKINS, 1937, p. 431). *Thracia villosiuscula* has a fourth aperture near the posterior end of the animal just below the inhalant siphon and exhibits a true tissue fusion (ATKINS, *op. cit.*, p. 431).

## SIPHONS

The siphons are transparent, separated and short (Figure 2). The basal region is covered with periostracum in which sand grains are incorporated. The cavity of the basal region represents a posterior extension of the mantle cavity (YONGE, 1952, p. 441). The base of each siphon is surrounded with many small tentacles. The aperture of the inhalant siphon is fringed with 9 simple tentacles. The exhalant siphon consists of a tapering tubular membrane without any tentacles between the aperture and the common outer ring. This arrangement is similar to that in *Lyonsia hyalina* as described by MORSE (1919, p. 161).

Regularly distributed black spots are found on both siphons; on the exhalant siphon the spots are concen-

trated in the lower part, forming a dark ring. Many spots are present on the tentacles of the inhalant siphon.

As in *Pandora*, the siphons are not capable of great extension, and for this reason the animal is more or less

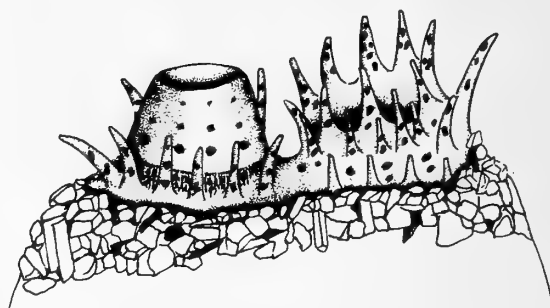


Figure 2

Appearance of fully extended siphons projecting out of the shell valves

limited to the epifaunal regions of the substrate (BOSS & MERRILL, 1965, p. 183).

As in *Glossus humanus* (LINNAEUS, 1758) specimens placed in a dish withdrew their siphons when a hand was placed lightly on the table on which the jar stood; this sensitivity is evidence that the animal normally inhabits quiet waters (OWEN, 1953, p. 92). The exhalant siphon contracts by lateral constriction of its sides forming a figure 8 when seen from above; this is followed by the infolding of the siphonal edges.

## THE MANTLE CAVITY

The disposition of the organs in the mantle cavity (Figure 3) is revealed after removal of the left shell valve and mantle lobe. The slightly smaller anterior adductor muscle (aam) and the larger posterior adductor muscle (pam) are situated in a line parallel with the dorsal margin. The important features of the different organs will be outlined below.

## THE CTENIDIA

The outer demibranch consists only of a direct lamella, which is upturned and attached near the dorsal surface (Figure 3). The inner demibranch is broad and reflected. RIDWOOD (1903, p. 150), KELLOGG (1915, p. 656) and ATKINS (1937, p. 351) noted that in allied species the same phenomenon occurs. The lamellae are deeply pli-

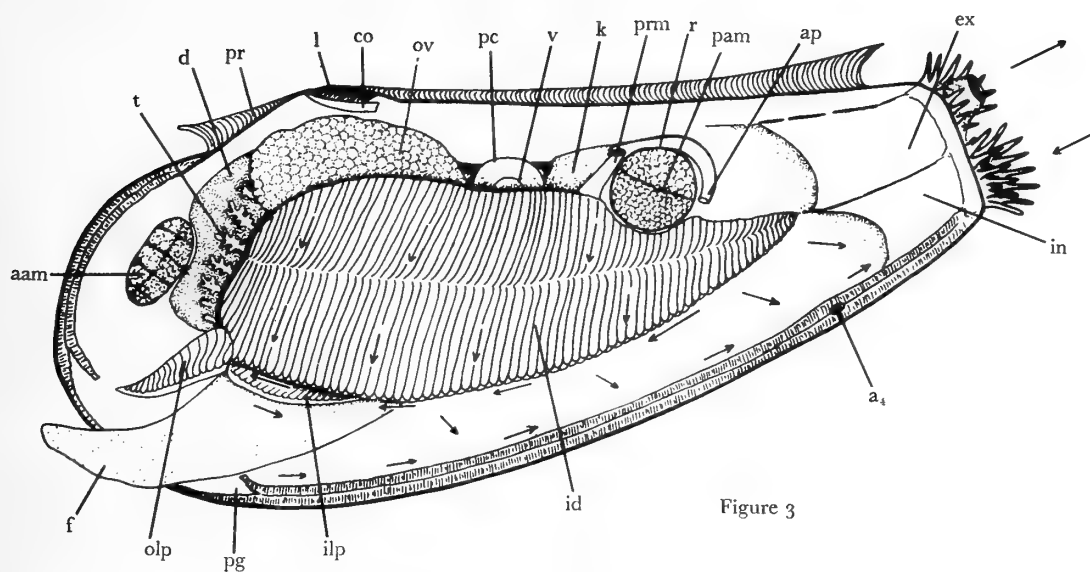


Figure 3

Figure 3

*Lyonsia californica* CONRAD

mantle cavity viewed from left side after removal of the left shell valve and mantle lobe

$a_4$  - 4<sup>th</sup> aperture  
 ap - anal papilla  
 ex - exhalant siphon  
 ilp - inner labial palp  
 aam - anterior adductor muscle  
 co - lithodesma  
 d - digestive diverticula  
 id - inner demibranch  
 in - inhalant siphon  
 k - kidney

l - ligament  
 pam - posterior adductor muscle  
 pg - pedal gape  
 prm - posterior retractor muscle  
 olp - outer labial palp  
 pr - periostracum  
 r - rectum  
 ov - ovary  
 pc - pericardium  
 t - testis  
 v - ventricle

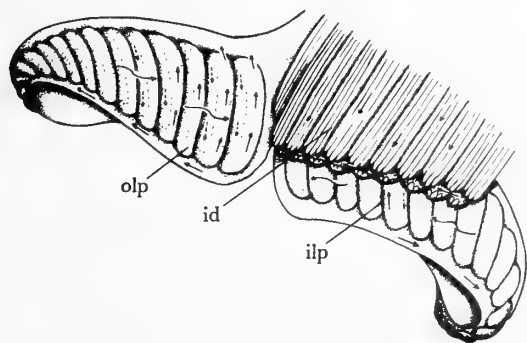


Figure 4

The labial palps of the left side. Shell length 19 mm

aam - anterior adductor muscle  
 ilp - inner labial palp  
 id - inner demibranch  
 olp - outer labial palp

cated and heterorhabdic. As in *Lyonsia norvegica*, 13 to 17 filaments form a plica, while the apical 5 are more strongly developed than the others. As with the remaining filaments, the apical filaments have a middle tract of long, coarse frontal cilia, bordered on each filament by tracts of fine, short cilia.

At the free edge of the inner demibranch there is a deep marginal groove (Figure 4). Ciliary currents were studied by the application of carmine, aquadag, and fine carborundum in minute quantities. The ctenidia are similar to those of *Lyonsia norvegica* (ATKINS, 1937, p. 350), *Mytilimeria nuttallii* (KELLOGG, 1915, p. 656) and *Entodesma saxicola* (KELLOGG, *op. cit.*, p. 659) and fall into ATKINS' Type E (ATKINS, *op. cit.*, p. 409).

Ciliary currents move downward to the margin of the outer demibranch and continue in the same direction on

the descending lamellae of the inner demibranch to its margin. On the two exposed faces of the ctenidium, particles are driven ventrally, therefore, while on the inner lamella of the inner demibranch, the movements of the particles are also ventral.

Along the marginal groove there is an oral current moving material on the ventral margin of the inner demibranch to be taken on the palp folds and passed to the mouth (Figure 4).

The ciliary mechanism on the ctenidia of *Lyonsia californica* is similar to that of *L. norvegica*, described by ATKINS (1937, p. 347).

Frontal cilia extend around the ventral ends of the filaments; they occur on both sides of each filament and beat toward the axial groove.

Latero-frontal cilia ( $10\mu$  in length) are situated on a slight ridge. The lateral cilia are very similar to those of *Lyonsia norvegica*.

With the ctenidium deeply plicated, the marginal food groove has scalloped sides. The marginal groove in *Lyonsia californica* is deep and similar to that of *L. norvegica* described by ATKINS (*op. cit.*, p. 350).

Fine particles reach the principal filaments and adjacent filaments within the plical grooves. The principal filaments end at the bottom of the marginal groove. Particles carried in the principal filaments and the adjacent filaments come to the same deep channel.

Coarse particles are kept from entering the narrow interplical space and are carried on the plical crests or passed directly off the ctenidia, or are passed toward the mouth to fall on the mantle where they are removed.

The animal could contract the ctenidia, covering the principal filaments, and thus exposing a reduced surface to the current being directed to the mouth.

The ventral tips of the anterior filaments of the inner demibranch are inserted and fused to a distal oral groove and fall in Category II of the association of ctenidia and labial palps (STASEK, 1963, p. 91).

### THE LABIAL PALPS

The labial palps are large, active and continually coiling. Each palp lamella bears 20 ridges on the inner surface. The inner demibranch of the ctenidium projects deeply between the palps. Particles form a narrow stream that moves in the oral groove, and are subjected to selection by the folds of the palps, eventually passing over them to the mouth. If material is not removed, it continues forward and is carried into the proximal oral groove.

Material bound in mucus which passed to the palp from the inner demibranch was rapidly transported anteriorly

and ventrally, being rejected at the free ventral margin of the palp.

The following ciliary currents may be recognized:

(a) On the floor of the groove between adjacent folds, particles are driven to the ventral border of the palp and from there moved to the tip of the palp where they are rejected (Figure 5 a, 5 b).

(b) On the crests of the folds and on the superficial slopes, particles are carried forward from fold to fold toward the mouth (Figure 5 a, 5 b).

(c) On the crests of the folds toward the dorsal border of the palp, particles are moved to the dorsal part of the labial palp where they form a resorting current.

In *Lyonsia californica* there is one main acceptance current, one rejection current and one dorsally directed resorting current (Figure 5).

Under normal conditions particles of carmine and carborundum are carried rapidly forward and downward over the folds, traveling over the folds without being

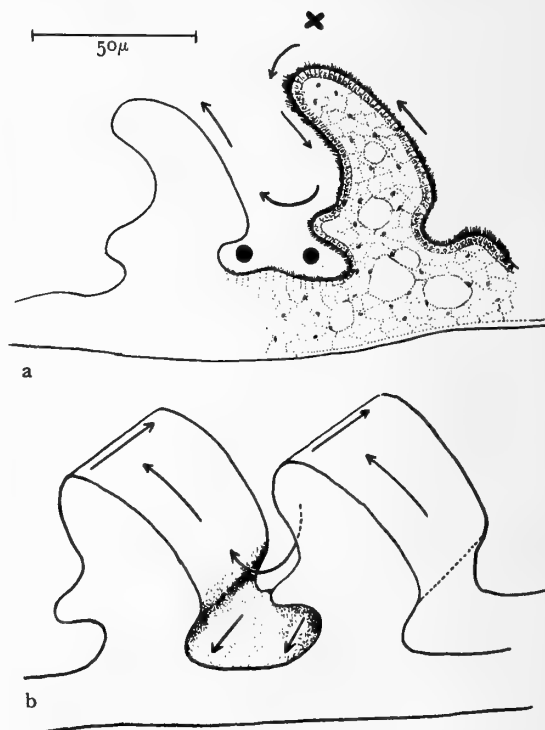


Figure 5

- a - Section of the labial palps; ● indicates the position of a proximal current; x indicates the position of a distal current; arrows show the direction of an oral current  
b - Diagrammatic representation of the ciliary mechanisms on the folded surface of the labial palps

deflected dorsally by the resorting current. However, some are taken on the crests of the ridges and transported dorsally by the dorsal resorting current. Particles are accumulated at the base of the palp and, with particles from the ctenidial margin, are passed into the lateral oral groove, then to the mouth where they are ingested.

Very few particles were carried in the deepest part of the grooves to be rejected by the free ventral border of the palp, as observed in *Petricola pholadiformis* LAMARCK, 1818 (PURCHON, 1955, p. 264).

### THE VISCERAL MASS AND THE FOOT

The visceral mass of *Lyonsia californica* is very similar to that of *L. norwegica*, as described by PELSENER (1891, p. 210). The digestive diverticula are placed anteriorly and ventrally, with the kidney posterior to the pericardium. This species is hermaphroditic, possessing two large pairs of gonads each with its own duct. The ovary occupies the dorsal region of the visceral mass and is surrounded by the testis which fills the ventral region of the digestive diverticula. Observations were made during the process of spawning, which occurred in April. Great numbers of eggs left the exhalant siphon followed in the same animal by a discharge of sperm. This alternation between the discharge of eggs and sperm continued for a few minutes. Fertilization occurs in the sea water as in *Entodesma saxicola* and *Mytilimeria nuttallii* (YONGE, 1952, p. 443).

The foot is slender, and, when fully distended, is half the length of the shell. There is a well developed byssus gland with a groove extending along the ventral side of the foot almost to its tip. The construction of byssus threads by adult animals was observed in the laboratory. YONGE (1952, p. 446) states that the foot and pedal gape are small in *Lyonsia norwegica*. *Lyonsia californica* is capable of burrowing. A specimen 20mm long was observed to bury itself in 25 minutes. Once buried, the animal remains in the same position for a long time, which is indicated by the algal growth on the posterior end of the shell valves.

### MUSCULATURE

The anterior adductor muscle of *Lyonsia californica* is smaller than the posterior adductor muscle, and both are located on the antero-posterior axis of the body.

The anterior pedal retractor muscle arises a short distance posterior to the anterior adductor, is poorly developed and its fibers spread out immediately below the

epidermis on the antero-dorsal surface of the visceral mass.

The posterior retractor muscle arises anteriorly to the posterior adductor muscle, is well developed and inserts at the postero-dorsal part of the visceral mass.

Transverse muscle fibers arise in the epithelium of the visceral mass and pass inward either to the walls of the alimentary canal or transversely across the visceral mass to the opposite side.

### THE ALIMENTARY CANAL GENERAL STRUCTURE

The alimentary canal (Figure 6) was dissected from specimens that had been relaxed with magnesium chloride and preserved in alcohol. The internal structures of the stomach were studied in living animals. The stomach was

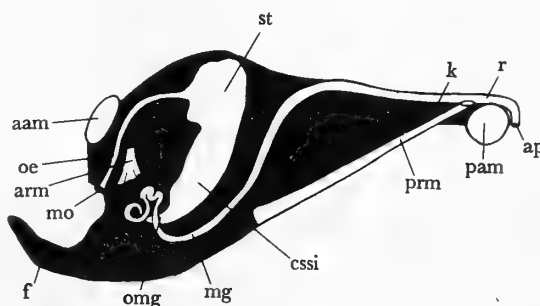


Figure 6

#### General dissection of the alimentary canal

- |  |                                 |
|--|---------------------------------|
| ap - anal papilla  | arm - anterior retractor muscle |
| csi - combined style and mid-gut                         | f - foot                        |
| mg - mid gut   | mo - mouth                      |
| omg - origin of the mid-gut at the base of the style sac | oe - oesophagus                 |
| pam - posterior adductor muscle                          | r - rectum                      |
| prm - posterior retractor muscle                         | st - stomach                    |

opened by a mid-dorsal incision through the roof, and the right side of the stomach was drawn downward (Figure 7). The ciliary currents were investigated with the aid of carmine, aquadag and fine carborundum particles. The nomenclature used by GRAHAM (1949), OWEN (1953), PURCHON (1955) and REID (1965) has been followed.

The mouth (mo) opens into a long oesophagus (oe) that enters at the anterior part of the stomach (st). The lumen of the oesophagus is dorso-ventrally compressed. The stomach consists of two parts: a globular anterior region and a posterior elongated region. The combined

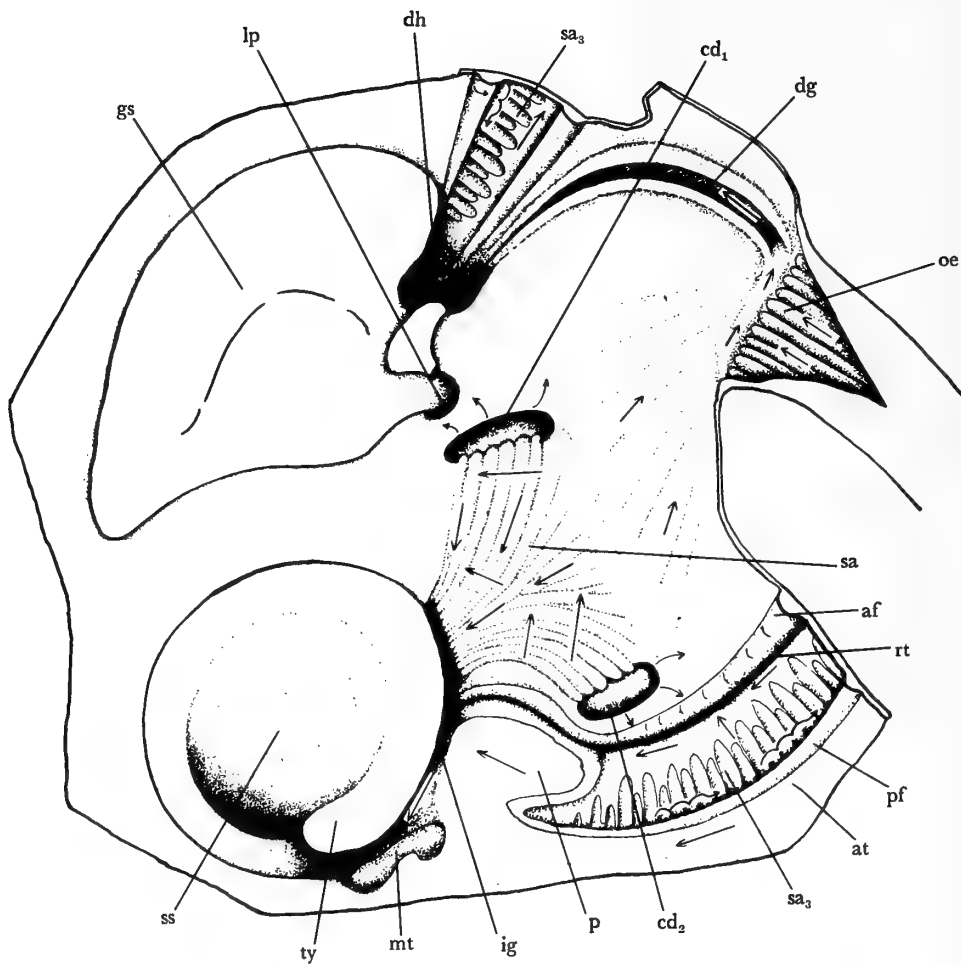


Figure 7

The interior of the stomach, seen from the right side, after opening  
by making an incision in the right wall

- |  |   |  |                  |                     |
|--|---|--|------------------|---------------------|
| af - anterior fold                     | at - acceptance tract                   | oe - oesophagus                          | p - ciliated pad | pf - posterior fold |
| cd <sub>1</sub> - left collecting duct | cd <sub>2</sub> - right collecting duct | rt - rejection tract                     |                  | sa - sorting area   |
| dg - dorsal groove                     | dh - dorsal hood                        | sa <sub>3</sub> - posterior sorting area |                  | ss - style sac      |
| ig - intestinal groove                 | lp - left pouch                         | ty - major typhlosole                    |                  |                     |
|  | mt - minor typhlosole                   |  |                  |                     |

style-sac and intestine open into the posterior and ventral region of the stomach. The intestine is convoluted in the region anterior to the stomach and then passes backward, proceeding posteriorly and dorsally over the kidney and the posterior adductor muscle to open at the anus.

### STRUCTURE OF THE STOMACH

*Lyonsia californica* has a stomach of Type 4 as defined by PURCHON (1958, p. 488). The minor typhlosole (mt) ends where the anterior globular part of the stomach begins, so that the intestinal groove (ig) running across the floor of this region has no fold along it on the right side, though its left margin is bordered by the extension of the major typhlosole (ty). The major typhlosole is thick, large, and extends across the opening of the mid-gut to come in contact with the minor typhlosole. As in other bivalves which have stomach Type 4, the major typhlosole and the intestinal groove pass forward over the floor of the stomach, curving gradually to the left. The major typhlosole does not possess a tongue, nor does it enter any of the orifices of the ducts from the digestive diverticula on the anterior right side of the stomach (PURCHON, 1958, p. 489).

The dorsal hood (dh) is large and directed anteriorly to the left. It opens posteriorly on the left wall of the stomach and arches forward above the oesophagus and opens into the stomach anteriorly. The ventral wall of the stomach is covered with a finely ridged sorting area, posteriorly bordering on the intestinal groove which disappears, on the right side of the major typhlosole, into the intestine. The sorting area is composed of a regular series of alternately long and short folds, separated from one another by grooves with diverse ciliary currents setting up a sorting mechanism. The posterior sorting area (sa<sub>2</sub>), which forms a Type A sorting mechanism (REM, 1965, p. 159), is well developed, extending dorsally over the right wall of the stomach and on to the right wall of the dorsal hood. The posterior margin of the sorting area is formed by a well developed fold (pf), while the anterior margin is bounded by the rejection ciliary tract (rt) which empties into the intestinal groove (ig) on the floor of the stomach at the point where the minor typhlosole ends. The anterior margin of the rejection tract is formed by a second fold with several small parallel ridges (af).

The gastric shield (gs) is well developed and attached to the left wall of the stomach by the teeth extending into the apertures of the left pouch (lp) and the dorsal hood. The left pouch is a blind hollow into which the anterior border of the gastric shield fits. This is similar to *Pandora*

*inaequivalvis* (PURCHON, 1958, p. 509). The left pouch of the Lyonsiidae falls into Section III, Group B of DINAMANI (1967, p. 262).

In the ventral part of the stomach wall there is a fan-shaped sorting area (sa), with a series of folds and ridges that have the same arrangement as the posterior sorting area, and drains particles into the intestinal groove. This well developed area extending from the mid-gut penetrates the two large apertures, one on the left anterior wall and the other on the right anterior wall. A similar condition exists in *Pandora*. The aperture of the left wall of the stomach was termed by ALLEN the "left caecum." In *Lyonsia californica* there are 17 to 20 folds, while in *P. inaequalis* there are 10 to 15. ALLEN (1954, p. 480) described this region as the "lateral rejection grooves." All ducts of the digestive diverticula open into the two larger apertures. Dissection of the main collecting ducts (cd) revealed the apertures of the ducts which open into them. Five ducts from the digestive diverticula open into the left aperture and 3 of them open into the right aperture of the stomach.

Particles accepted by the palps are carried through the oesophagus and carried to the roof of the stomach by the dorsal groove (dg), where they are caught by the tip of the crystalline style and directed to the posterior sorting area by its revolving action. The crystalline style in *Lyonsia californica* is large (7 mm long in a specimen of 19 mm overall length) and rotates in a clockwise direction when viewed from above. The particles in the posterior sorting area are directed against the ridges of the anterior fold. From here they are carried by the revolving style to the ridged surface of the posterior sorting area, where heavier particles are carried by the cilia of the grooves to the rejection tract (rt) and to the mid-gut by the intestinal groove (ig). The finer particles are conveyed dorsally from crest to crest across the ridges. Only the lighter particles are retained in the distal region of the dorsal hood, where they are included in the mass at the tip of the crystalline style. The acceptance tract (at) conveys particles along the roof of the dorsal hood and over the posterior wall of the stomach to the mid-gut.

The ciliary currents of the dorsal region convey fine particles from the tip of the style to the acceptance tract. Particles in the sorting area (sa) are conveyed in the grooves, by cilia, to the intestinal groove. Cilia on the crests of the folds beat from the right to the left, carrying particles to the left region of the stomach. Here, coarse particles are rejected in the grooves, while fine material passes across this region on the crests of adjacent ridges by ciliary action.

Particles that do not enter the digestive ducts are carried towards the oesophageal region of the stomach

where they join others that come from the oesophagus, and then both are carried to the base of the dorsal hood by the dorsal groove. The dorsal groove was noted by ALLEN (1948, p. 480), but not by PURCHON (1959, p. 509) in *Pandora inaequalvalvis*.

The stomach of *Lyonsia californica* is similar to that of *Pandora inaequalvalvis*. The single duct from the digestive diverticula which ALLEN (1954) established as entering the middle of the floor of the stomach and which he erroneously interpreted as "right caecum" (PURCHON, 1958, p. 508), and not seen by PURCHON in the same species, is not present in *Lyonsia californica*.

## DISCUSSION

*Lyonsia californica* is adapted to live in a substratum of soft mud, and is found on muddy beaches. Algal growth confined to the siphonal region indicates that the animal buries itself in such a way that only the posterior part of the shell and siphons are exposed. The siphons are sensitive, and it is not probable that large quantities of material are normally taken into the pallial cavity. The siphons are short and never extend more than a few millimeters beyond the end of the shell.

The species has a well developed foot used to dig, and to orientate the animal when it digs.

The animal lives in quiet waters with little disturbance of the bottom deposits so that the water contains little suspended material. The presence of well developed sorting areas in the stomach is evidently desirable to reject large particles or excessive quantities of small particles (PURCHON, 1960, p. 487).

The stomach is very similar to that of *Pandora inaequalvalvis*, which was studied by ALLEN (1954) and PURCHON (1958). In *Lyonsia californica* there is no simple duct from the digestive diverticula that PURCHON named DDD<sub>3</sub> and which ALLEN (1954, p. 480) interpreted as the right caecum and established as entering the floor of the stomach and communicating with the intestinal groove by a special groove. PURCHON (*op. cit.*, p. 508) was unable to find this duct in the animals that he studied but he inserted it later, as he said, in the figure of the stomach of *P. inaequalvalvis*.

In *Lyonsia californica* the major typhlosome accompanied by the intestinal groove passes toward the openings of the collecting ducts and curves across the opening of the mid-gut to come into contact with the minor typhlosome. PURCHON believed that in *Pandora inaequalvalvis* the major typhlosome and the intestinal groove terminate at the posterior border of the mouth of the collecting duct, which is situated on the left anterior wall of the stomach.

As PURCHON found in *Pandora inaequalvalvis*, the digestive diverticula do not open into the left pouch.

A groove on the roof of the stomach and in which cilia beat backward and convey particles toward the dorsal hood, exists in *Lyonsia californica*, and this was also found in *Pandora inaequalvalvis* by ALLEN. It was not seen by PURCHON when he studied the same species of *Pandora*.

The stomach of *Lyonsia californica* resembles in general the stomach of *Anodonta cygnea* (GRAHAM, 1949, p. 745), but is much more similar to that of *Pandora inaequalvalvis*.

PURCHON (1958, p. 488 and 1960, p. 432) made an intensive study of the stomach in Bivalvia and found in 22 families the stomach that he defined as Number 4. The family Lyonsiidae is now the 23<sup>rd</sup> family known to have this type of stomach.

Of 4 families in the super-family Pandoracea of the sub-order of Anomalodesmacea (ABBOTT, 1954, p. 468) we know that 2 have stomach type Number 4, Pandoridae and now Lyonsiidae. Future studies will prove if in the remaining 2 families, Periplomatidae and Thraciidae, the stomachs are of the same type as defined by PURCHON, proving that the form of the stomach is an indication of the phylogeny of the bivalves and not a consequence of the adaptations to different environments.

## SUMMARY

*Lyonsia californica* CONRAD occurs in muddy substrates on the Pacific coast of North America from Puget Sound to Lower California. The calcareous shell is thin and largely nacreous. The periostracum is very thick and sand grains adhere to it. A lithodesma is present and dorsally the shell valves are united by the periostracum. The mantle edges are fused except in the region of the small fourth pallial aperture and along the relatively well developed pedal gape.

The anatomy and functioning of the stomach is described in detail. It belongs to type Number 4 as defined by PURCHON (1958, p. 488). The stomach of *Lyonsia californica* is similar to that of *Pandora inaequalvalvis*.

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# Structure of the Bivalve Rectum

## II. Notes on Cell Types and Innervation

BY

THOMAS C. JEGLA

Department of Biology, Kenyon College  
Gambier, Ohio 43022

AND

MICHAEL J. GREENBERG

Department of Biological Sciences  
Florida State University, Tallahassee, Florida 32306

(Plates 45 to 48)

### INTRODUCTION

RECENTLY, THERE HAS BEEN increasing interest in the pharmacology (GREENBERG & JEGLA, 1963; GREENBERG, 1966; PHILLIS, 1966) and physiology (PROSSER, NYSTROM & NAGAI, 1965; NYSTROM, 1967) of the bivalve rectum as an example of an invertebrate organ with smooth muscle. While these studies have all been concerned with the innervation of the nonstriated muscle of the rectum, the histology of this structure has been but briefly noted (GREENBERG & JEGLA, 1962; PHILLIS, 1966).

Although the structure of molluscan muscles has been intensively studied (see HANSON & LOWY, 1960, 1965; HOYLE, 1964), the bulk of these investigations have concerned skeletal muscles such as shell adductors and byssus retractors. Consequently, with the exception of work on heart (reviewed by HILL & WELSH, 1966; NISBET & PLUMMER, 1966), visceral musculature has largely been ignored.

We have shown that the gross histology of bivalve rectums varies markedly from species to species (JEGLA

& GREENBERG, 1968). Also, GREENBERG (1966) described striking pharmacological differences between the acetylcholine responses of two intrageneric species. In the present study we have looked for specific differences in the cellular elements which might be correlated with gross structural or pharmacological differences. In addition we have made observations of the pattern of innervation of the rectal musculature of some species. Finally, we have compared the structure of the rectal muscle fibers with those of the heart and other molluscan muscles.

### MATERIALS AND METHODS

The species of bivalve mollusks and methods used in this study were identical to those previously reported (JEGLA & GREENBERG, 1968). In addition, for observation of nerves, we have used a modification of Bodian's silver staining technique as well as the method of KOELLE (1951) for acetylcholinesterase.

### Explanation of Plate 45

Figure 1: A transverse section through the wall of a *Mya arenaria* rectum showing the columnar epithelium, a layer of collagen fibers and circular muscle arranged in bundles.

C - columnar epithelium  
CTF - connective tissue fibers  
M - muscle cell

Figure 2: *Quadrula quadrula* (RAFINESQUE, 1820). Muscle is arranged in bundles and embedded in a network of connective tissue.  
Figure 3: *Amblema plicata* RAFINESQUE, 1820. Connective tissue in the typhlosole.

CM - circular muscle  
F - fibroblast cell  
P - phagocyte

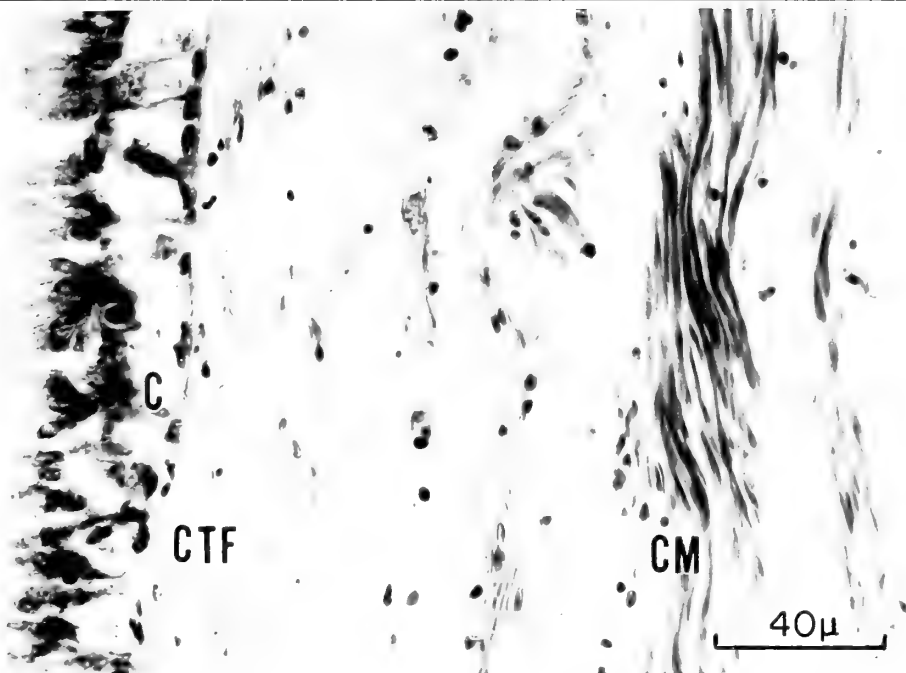


Figure 1

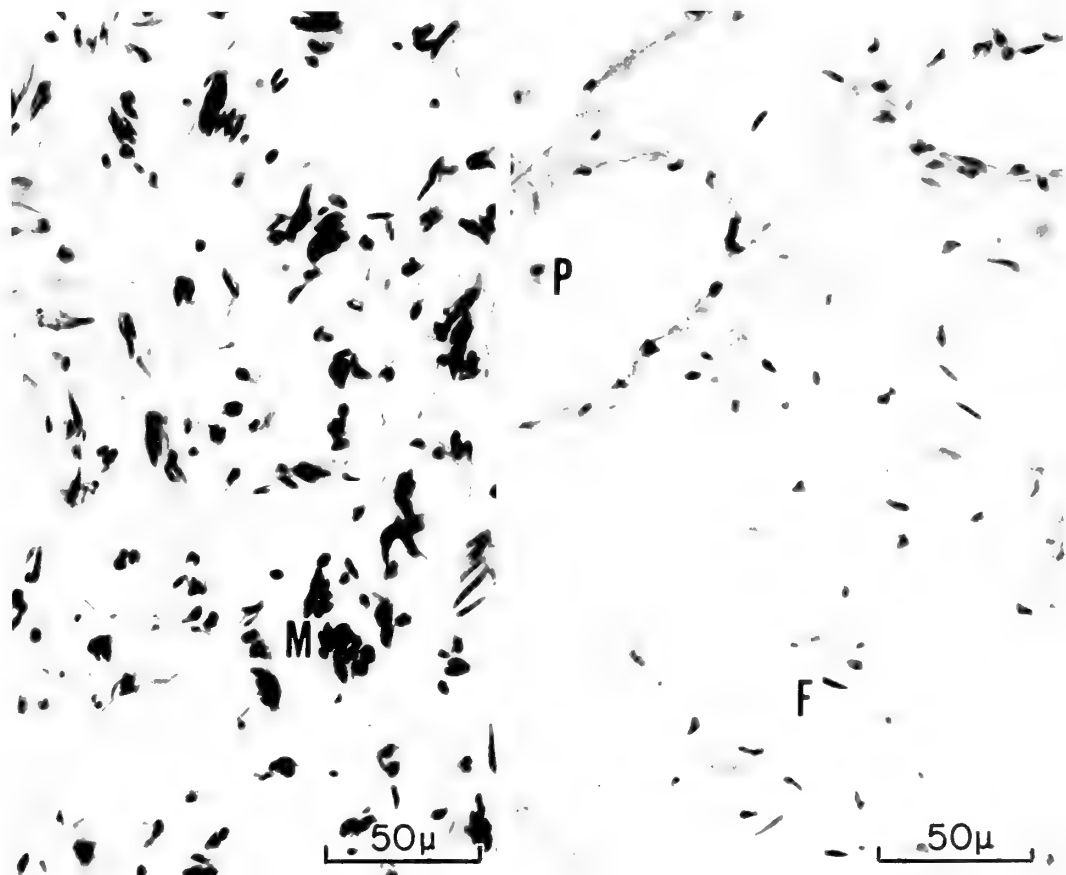


Figure 2

Figure 3



## RESULTS

The wall of the bivalve rectum is composed of an inner columnar epithelium, connective tissue, and muscle layers (Figure 1). The epithelium is separated from the more peripheral elements by a basement membrane. These elements, as well as innervation of the muscle are discussed below.

### Epithelial Cells

Details of the columnar epithelial cells lining the digestive tract lumen in *Anodonta cellensis* SCHRÖTER, 1779 (see GUTHEIL, 1912) and *Ostrea edulis* LINNAEUS, 1758 (see YONGE, 1926) have been described. Only a few additional comparative observations will be given here. These cells are much higher than wide but their average height varies depending, not only on the species, but also on the size of the individual animal. The smallest cells were found in *Nucula* ( $7.5\mu$ ) and the largest in *Mytilus californianus* CONRAD, 1837 ( $115\mu$ ). In a very small *Actinonaias carinata* (BARNES, 1823) the average cell height was about  $26\mu$ , while in a large specimen of the same species, it was about  $74\mu$ . In some species, height of the cells may vary greatly around the periphery of the lumen; this is observed in conjunction with ridges and furrows, and with typhlosoles. In *Mytilus edulis* LINNAEUS, 1758 the columnar cells are twice as large on the ventral side of the rectum as they are on the dorsal side (see Part I, plate 37, fig. 3). The reverse situation occurs in *Actinonaias* (see Part I, plate 39, fig. 7) and other unionids. Furthermore, the cytoplasm of the small cells bordering the unionid typhlosole stains more intensely than that of the taller cells on the opposite side of the rectum.

DAKIN (1909) thought that cilia are poorly developed in the rectum of *Pecten maximus* (LINNAEUS, 1758), and WHITE (1937) reported that cilia are long but scantily developed in the rectum of *Mytilus edulis*. However, rectal cilia were fairly abundant in all the species we studied. The mean length of the cilia in most species was between  $6\mu$  and  $12\mu$ . Conspicuously smaller cilia were observed in *Nucula* and *Dinocardium robustum* (LIGHTFOOT, 1786) [about  $4\mu$ ], and larger cilia in *Chlamys* and *Mya arenaria* LINNAEUS, 1758 ( $15\mu$  to  $16\mu$ ).

Mucous cells and phagocytes occur in the columnar epithelial layer and were described by YONGE (1926) in *Ostrea*, and by GUTHEIL (1912) in *Anodonta*. The fibrous nature of the underlying basement membrane is easily observed in *Atrina rigida* (LIGHTFOOT, 1786) (Plate 46, Figure 4). There is some small interspecific variation in thickness of this membrane but in all species

it is thin ( $1\mu$  to  $5\mu$ ). The outer surface of the rectum is covered by a very thin epithelium which is observed only with difficulty.

### Connective Tissue Fibers and Cells

The numerous, randomly oriented fibers in the rectum have the staining properties of collagen (Plate 45, Plate 46, Fig. 4). They are considerably smaller than the average muscle fiber, and are less than  $1\mu$  in diameter. Their length is not known because they are contorted and their ends could not be observed in histological sections. This feature is shared with the collagen fibers in vertebrate connective tissue. A reticulum of very small fibers is frequently observed around the individual muscle fibers.

The prominent cellular elements of the connective tissue are phagocytes, fibroblasts, and vesicular cells. Phagocytes are numerous among the columnar cells, throughout the wall of the rectum and in the circulation. These cells were described extensively by GUTHEIL (1912) and YONGE (1926). While the amount of cytoplasm is variable, the nucleus is spherical, small ( $2.5\mu$  to  $4\mu$  in diameter), and hyperchromatic (Plate 45, Fig. 3); these characteristics serve to distinguish a phagocyte from any other cell in the rectum.

Fibroblast cells are a universal and common component of the connective tissue. They are fusiform or stellate-shaped, with fibrous processes extending from the cell body. The fusiform type is  $2.5\mu$  by 4 to  $12\mu$  in size; it has one or two fibrous extensions and the nucleus occupies most of the cell body (Plate 45, Figure 3). The stellate cells average  $5\mu$  by  $7\mu$ ; they have three or more long fibrous extensions and a small spherical nucleus. Fibroblasts are best observed in typhlosoles, since they are filled, principally, with fibrous connective tissue.

The rectums of a few species have vesicular cells that are spherical to oval in shape. These are the largest connective tissue cells in the rectum (up to  $13\mu$  by  $40\mu$ ); they resemble those cells surrounding the digestive tract in the visceral mass. Generally, vesicular cells are empty after fixation; the sparse cytoplasm and small nucleus are located centrifugally.

### Muscle

At the light microscope level all of the muscle fibers in the bivalve rectum are nonstriated. They are spherical or oval in transverse section (Plate 46, Figure 5), and have a diameter of  $1\mu$  to  $6\mu$ ; the larger diameters may be the result of contraction. The fibers are very long, at least  $170\mu$ , but we were unable to determine their exact length. The muscle cells are uninucleate; the nucleus is large, oval, and with its major axis parallel to the longi-

tudinal axis of the fiber (Plate 46, Figure 5). In all species the muscle nuclei can be distinguished from those of fibroblasts by the larger size and lighter staining quality of the former.

The fibers are arranged in bundles in *Mya* (Plate 45, Figure 1) and the family Unionidae (Plate 45, Figure 2), but there is little indication of such grouping in Cardidae or Mactridae which have the muscle fibers packed closely together throughout the area of their occurrence in the rectum. In those species with a scarcity of muscle, and in the Veneridae, the muscle cells are generally not organized into bundles but lie embedded as individual units in the meshwork of connective tissue fibers and cells (Plate 47, Figure 6).

HANSON & LOWY (1957) distinguished three kinds of molluscan nonstriated muscle on the basis of the distribution, in the cell, of myofibrils, the course (*e. g.* helical or straight) of the myofibrils, and the appearance of "contraction bands" during excessive shortening of the muscle. We have examined these characteristics.

Myofibrils are not restricted to the periphery of the fiber in the rectum. While this is especially clear in transverse sections of *Dinocardium* muscle (Plate 46, Figure 5), an even distribution of fibrils in the sarcoplasm has been found in all of the species examined.

Rectums of *Mercenaria mercenaria* (LINNAEUS, 1758), fixed either while tied at an extended length, or while in 5-hydroxytryptamine contracture, were compared. In the stretched rectum, the smallest fibers have the classic appearance of vertebrate smooth muscle; no myofibrils are visible. But the larger fibers have longitudinal fibrils lying parallel to the long axis; they were not helically arranged. We were unable to determine the length of these fibrils. In *Mercenaria* rectums highly contracted by 5-hydroxytryptamine, many of the fibers appear to have contraction bands which cross each other at angles of up to 20° to the fiber axis, producing the classical double-oblique, or diamond lattice pattern. Many of our preparations from other species also showed this pattern following fixation or 5-hydroxytryptamine contracture (Plate 46, Figure 5).

### Comparison of Heart and Rectal Muscle

The nonstriated muscle fibers of the heart of *Mercenaria* are different from those of the rectum in that the myofibrils are peripherally disposed (Plate 47, Figure 7). This difference in the distribution is probably not due to artifact since both tissues were necessarily fixed, embedded and stained together. However, NISBET & PLUMMER (1966) examined the fine structure of the heart of achatinid snails and found that the contractile elements were centrally disposed in the muscle cells, occupying about  $\frac{2}{3}$  of the cross-sectional area.

The myofibrils of the *Mercenaria* heart appear to spiral and helical "contraction bands" were observed (Plate 47, Figure 8). Often the fibrils are observed to cross at acute angles, producing the classic diamond lattice pattern of MARCEAU (1905, 1909). A reticulum of very fine connective tissue fibers surrounding individual muscle fibers was often observed. Larger collagen fibers and fibroblast cells are found between the heart muscle cells. Nuclei are centrally placed and appear to be more numerous in heart muscle; perhaps the fibers are shorter, or syncytial as was proposed for the *Mercenaria* heart (LOVELAND, 1963).

### Nervous Tissue

Intrinsic nerve fibers and cells have not often been demonstrated in bivalve muscles. BRÜCK (1914) illustrated small nerve fibers ending in motor end plates on muscle cells. BOWDEN (1958), using the cholinesterase technique of KOELLE (1951), demonstrated small nerve fibers and motor end plate-like structures in the fast part of the adductor muscles of *Anodonta* and *Unio*; in other muscles studied, only free terminations were observed. BOWDEN also reported ganglion cell-like structures and nerve fibers in the slow parts of bivalve adductors. PHILLIS (1966) observed small nerve fibers and a ganglion cell in the rectum of *Tapes watlingi* IREDALE, 1958.

Occasionally we have seen ganglion cells and nerve fibers in the rectum of *Dinocardium*. The nerve fibers bifurcate near their ends and terminate on different

### Explanation of Plate 46

Figure 4: *Atrina rigida* (LIGHTFOOT, 1786). Shows the fibrous nature of the basement membrane.

Figure 5: *Dinocardium robustum* (LIGHTFOOT, 1786). Muscle cells of the rectum in longitudinal and transverse section. Note the

BM - basement membrane

N - nucleus

distribution of myofibrils in the transverse section and the occurrence of the diamond lattice pattern in the longitudinal sections of muscle cells.

C - columnar epithelium

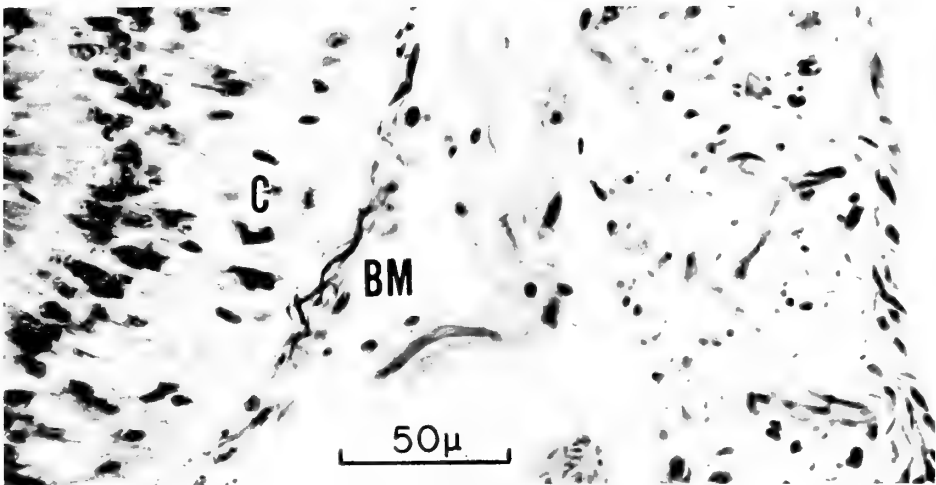


Figure 4

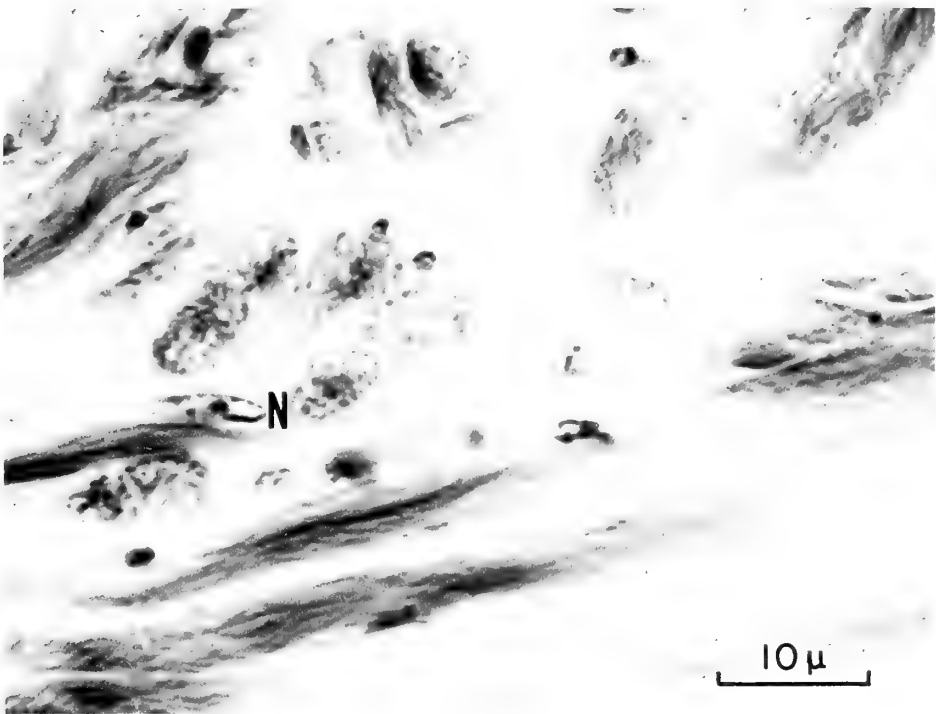


Figure 5



muscle cells. Nervous tissue was also demonstrated in *Mercenaria mercenaria* rectum with silver staining and the cholinesterase technique of KOELLE (1951). Apparently a nerve plexus lies at the base of the epithelial cells lining the lumen; fine nerve fibers run transversely (peripherally) from the plexus (Plate 48, Figure 9). Longitudinal collateral fibers are given off by these radial nerves which finally branch and terminate on muscle fibers (Plate 48, Figure 10). In addition, larger nerve fibers were also found running parallel to longitudinal muscle, then branching, with the small arborizations coursing transversely to end, again, on individual muscle fibers. Occasionally we have observed small unipolar and bipolar ganglion cells ( $2\mu$  by  $5\mu$ ) with fine, branching fibers. We have infrequently observed end plate-like structures in *Mercenaria* and *Dinocardium* rectums. Mostly, the nerve-muscle junctions were of the *en passage* type with only a small increase in density of staining where the nerve fiber lay athwart the muscle cell.

## DISCUSSION

The structure of the bivalve rectum, in each species, is different from that of the more anterior intestinal portion of the gut (VOGT & YUNG, 1888; GUTHEIL, 1912; YONGE, 1926; GALTISOFF, 1964). For example, the musculature is usually better developed or, at the least, a denser network of connective tissue is present in the rectum. Also, the number of cilia in the rectum has been reported as being smaller than in the intestine. The physiological significance of such differences is not clear, but there have been suggestions.

GUTHEIL (1912) believed that longitudinal and circular muscle layers in the rectum of *Anodonta cellensis*, which are absent in the intestine, provide support for the rectum where it hangs free in the pericardial and ventricular cavities. However, this hypothesis would appear to be contradicted by the fact that many species, regardless of rectal size, have little or no tissue peripheral to the basement membrane (e.g., *Nucula* and *Macoma*).

Probably no peristalsis occurs in the intestine; material is moved along the tract by the ciliated columnar epithelium. GUTHEIL noted (1912) that, while contractions in the intestine would be impeded by the surrounding tissue of the visceral mass, peristaltic action might occur in the freely suspended, muscled, scantily ciliated rectum. In fact, spontaneous contractions of *in vitro* preparations of rectums have been observed in *Mercenaria mercenaria* by GREENBERG & JEGLA (1963), *Tapes watlingi* by PHILLIS (1966), *Spisula solidissima* (DILLWYN, 1817) by PROSSER, NYSTROM & NAGAI (1965) and NYSTROM (1967) and in other bivalves (see GREENBERG, 1966).

PROSSER *et al* also observed spontaneous contractions and associated electrical activity in *in vivo* preparations of the *Spisula* rectum.

The histological architecture of the bivalve rectum supports the view (PROSSER *et al*, 1965) that conduction in this organ is by way of nerves rather than muscle. In most muscular bivalve rectums there is a large amount of connective tissue in which the muscle cells are embedded. Even in those species where muscle bundles are found (*Mya* and Unionidae), there are usually many individual fibers scattered through the collagen fiber network. Such an arrangement of the muscle appears to preclude electrical conduction from cell to cell such as occurs in the vertebrates and Echinodermata (PROSSER *et al*, 1965). Furthermore, our observations of silver-impregnated preparations of *Mercenaria* rectum indicate that while longitudinal nerve fibers are present, they are small. And PROSSER, NYSTROM & NAGAI (1965) found the conduction velocity in the *Spisula solidissima* rectum (8-9 cm/sec at 20°C) to correspond to conduction in such small, non-myelinated nerve fibers.

A wide array of physiological and pharmacological experiments, with rectums from a variety of bivalve species, have led to two broad predictions concerning the pattern of innervation of the musculature (GREENBERG & JEGLA, 1963; PROSSER *et al*, 1965; PHILLIS, 1966): Firstly, there ought to be ganglion cells present. These have been demonstrated by PHILLIS (1966), and we have now seen them in *Mercenaria* and *Dinocardium*. Secondly, there should be multiple innervation of the muscle cells. In fact, PROSSER *et al* (1965) proposed that inhibitory as well as both slow and fast excitatory fibers innervate the rectum of *Spisula solidissima*. While we have not observed innervation of muscle cells by more than one nerve fiber, only a portion of a particular muscle fiber appears in any one histological section. Furthermore, since nerve fibers are difficult to observe, multiple innervation is not ruled out.

Recently, BURNSTOCK, GREENBERG, KIRBY & WILLIS (1967) studied the rectum of the chiton, *Poneroplax*. They were able to correlate the electrophysiology of muscle with its innervation. Thus, the intestine, which acts like "unitary" smooth muscle (see BURNSTOCK, HOLMAN & PROSSER, 1963), was markedly less densely innervated than the rectum which had the properties of a "multiunit" muscle. So far, no such correlation between structure and function has been made with bivalve intestinal muscle.

The muscle fibers in bivalve rectums appear to belong to HANSON & LOWY's (1957) second of three major types of molluscan smooth muscle distinguishable in the light microscope; namely, a smooth muscle having the

classical appearance at physiological lengths and oblique or helical bands at excessively short lengths. In relaxed or stretched rectums the muscle fibers of bivalve molluscs are without visible fibrils or have fibrils paralleling the long axis of the fiber, whereas in highly contracted rectums dense bands appear in the fibers which give the appearance of a diamond lattice pattern. The myo-fibrils do not appear to be helically wound around the periphery as they are in the heart, but are dispersed throughout the core of the fiber.

### ACKNOWLEDGMENTS

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### Explanation of Plate 47

#### *Mercenaria mercenaria* (LINNAEUS, 1758)

Figure 6: Muscle cells in the rectum lie embedded as individual units in the meshwork of connective tissue.

Figure 7: Myofibrils in heart muscle cells cut in transverse section.

Note the peripheral distribution of the fibrils.

Figure 8: Heart muscle cells in longitudinal section. Note the "contraction bands."

CB - helical "contraction bands"

M - muscle cell

### Explanation of Plate 48

#### Nervous tissue in the rectum of *Mercenaria mercenaria* (LINNAEUS, 1758)

Figure 9: Note the small nerve fibers coursing transversely over the muscle cells.

Figure 10: Note the branching nerve fiber and the termination of a nerve fiber on a muscle cell.

F - fibroblast cell

M - muscle cell

NF - nerve fiber

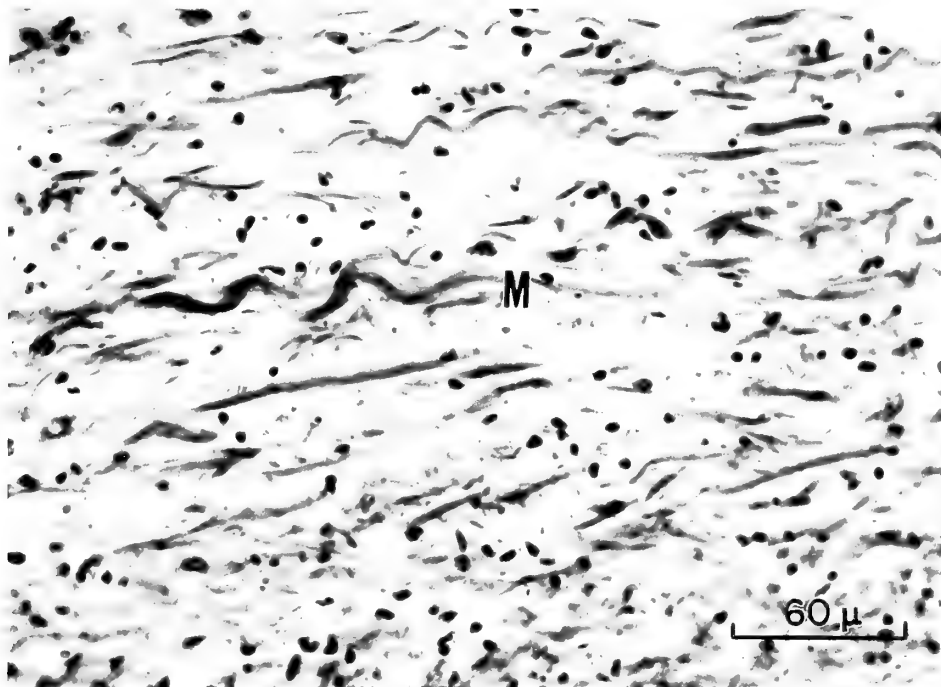


Figure 6

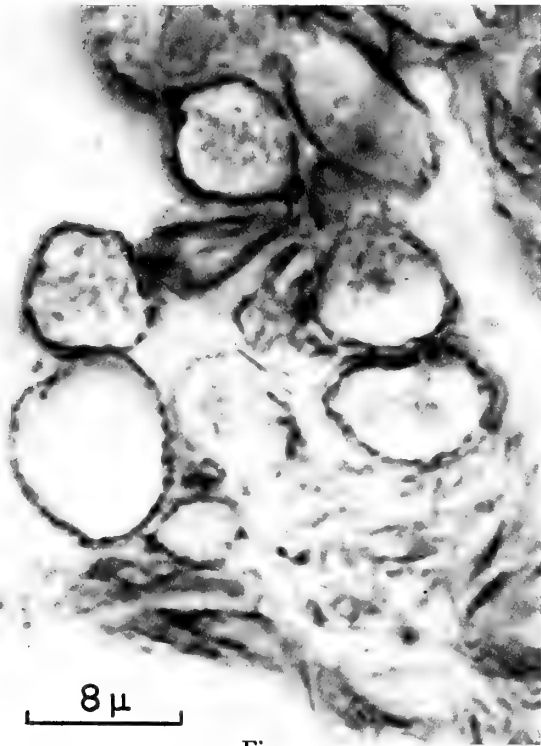


Figure 7

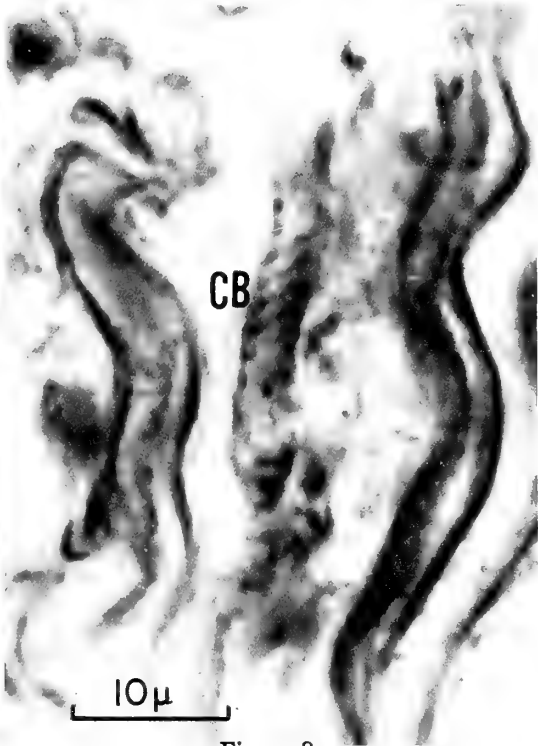


Figure 8



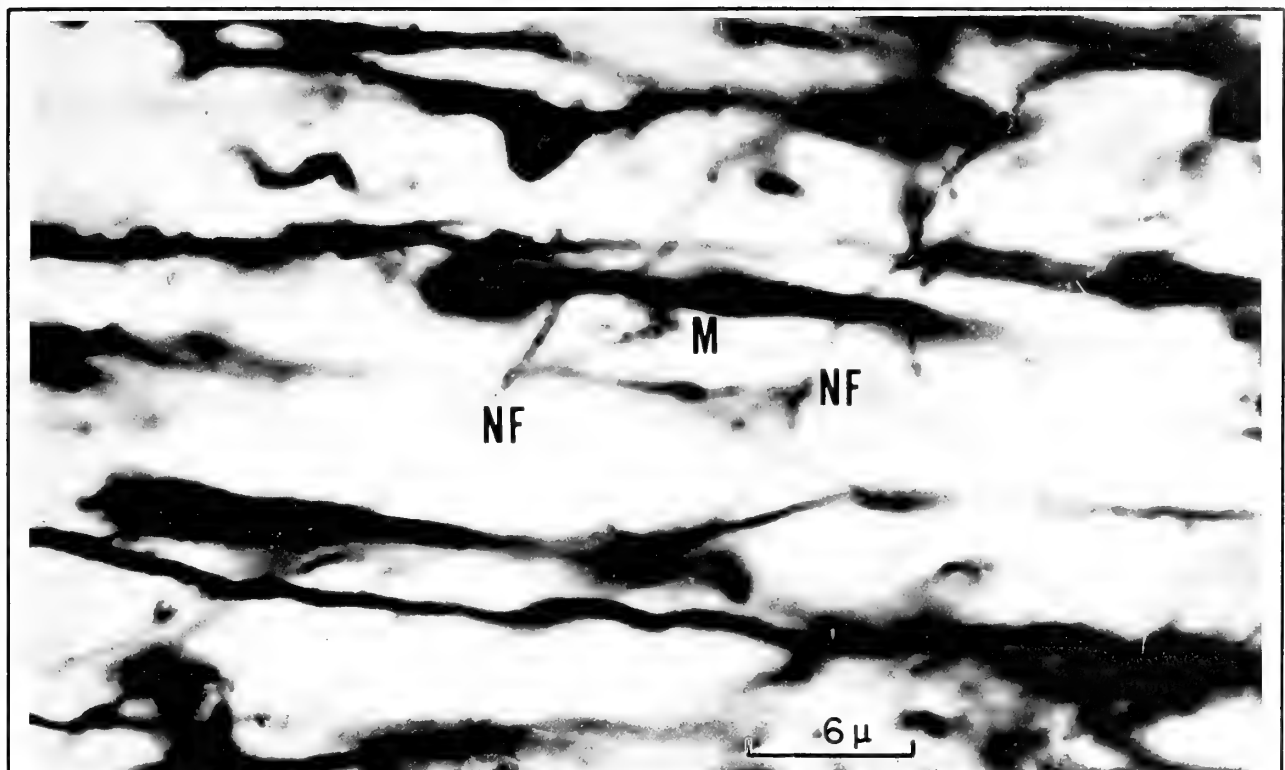


Figure 9

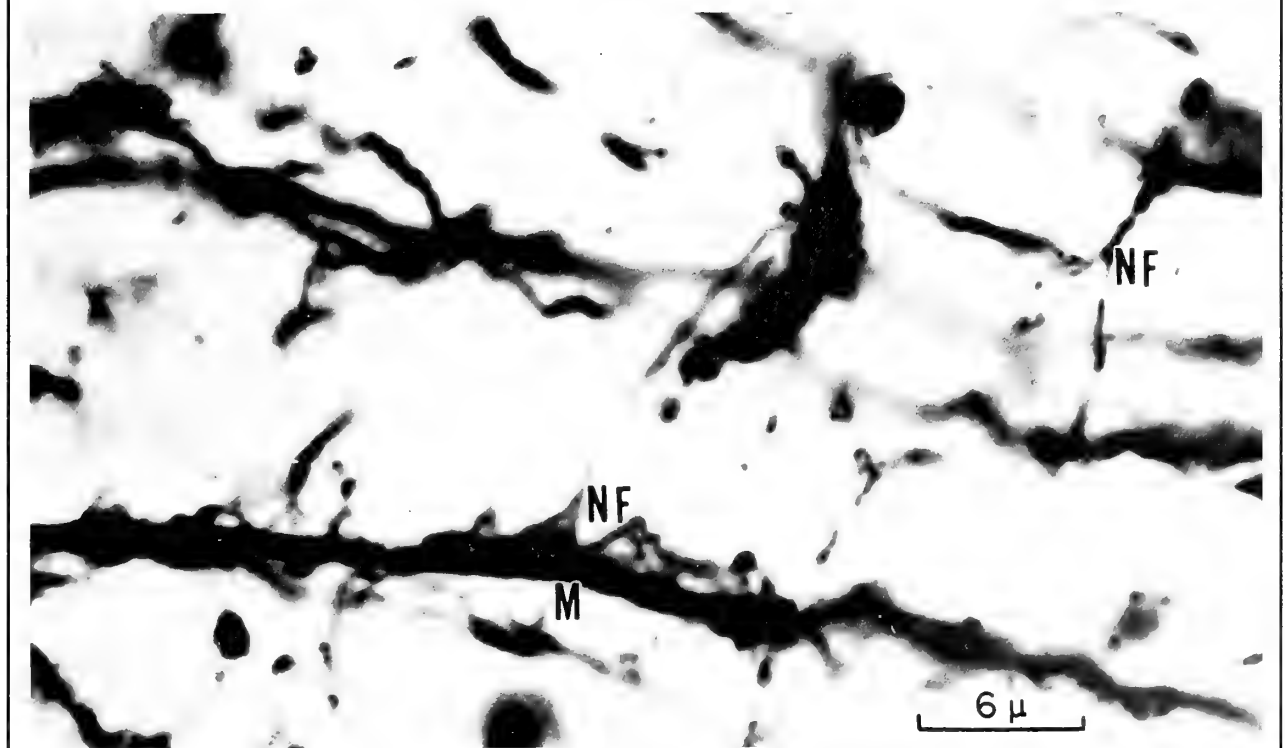


Figure 10



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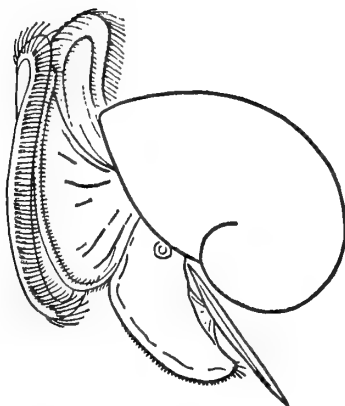
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# Role of Snails' Disease in the Biological Control of *Achatina fulica* BOWDICH, 1822 in the Andamans

BY

P. D. SRIVASTAVA

AND

Y. N. SRIVASTAVA

Division of Entomology

Indian Agricultural Research Institute, New Delhi - 12, India

A LEUCODERMIA-LIKE DISEASE of the giant African snail was observed to cause heavy mortality in our laboratory culture in 1965 (SRIVASTAVA, 1966). Since then experiments have been in progress to see if it could be made use of to control field populations. VAGO (1955) has studied 10 different diseases of several species of snails in France and has also reported the mortality of as many as 50 000 snails in "snail parks." MEAD (1959) is tempted to believe that diseases "successfully hold most snail populations in check and produce a major effect in population fluctuations." He has also predicted that in course of time a number of snails' diseases would be found and reported upon. However, enough data to show the definite effect of diseases on the populations of snails are lacking.

In the course of the survey of the giant African snail and its natural enemies on the Andaman Islands since 1965, some snails, dead and dying with disease, were observed in the laboratory culture as well as in the field population. The diseased snails were inactive, suspended

and finally stopped feeding. This confirmed the existence of the disease in the snail on the Andamans. The diseased snails collected from the field as well as picked up from the laboratory culture were placed in a field cage of the size of 10' x 10' x 10', overpopulated with normal snails and having an excess of moisture, the two requirements for the development of disease in snails. This resulted in mass mortality in the field cage, proving conclusively that the disease can spread through contact. Diseased snails were crushed and their aqueous extracts sprayed over healthy snails in the field cage to see if this technique would help in spreading the disease. This was repeated twice and the results are tabulated in Table 1.

From Table 1 it is clear that within about a week of the date of spraying the diseased snails' extract over the healthy ones, all the snails died. This method was then adopted to spread the disease in the field population of snails in three heavily infested localities; it was successful

Table 1

Field cage trials with diseased snail's extract spray

Sl. No.	Number of diseased snails crushed	Date of spraying	Date of observation	Total number of healthy snails introduced	Number of dead snails	Number of living snails	% mortality	Remarks
1	6	9 VI 1967	13 VI 1967	1650	1350	300	81.8	No mortality was observed in the snails kept under similar conditions except that they were not sprayed with diseased snail's extract
			16 VI 1967	0	220	80	73.3	
			18 VI 1967	0	80	0	100	
2	2	19 VI 1967	23 VI 1967	180	127	53	70.5	
			25 VI 1967	0	53	0	100	

Table 2

Field trials with diseased snails' extract spray

Sl. No.	Date of spraying	Date of observation	Locality	Result	Remarks
1.	21 VI 1967	23 VI 1967	Humphri Ganj	No mortality due to disease observed or reported	Soon after spraying it rained heavily on 21 VI 1967
		27 VI 1967	Humphri Ganj	No mortality observed or reported	On 23 VI 1967 it rained heavily throughout
		29 VI 1967	Humphri Ganj	No mortality observed or reported	
2.	27 VI 1967	29 VI 1967	Manglutan	Population of snails reported less	No rain soon after spraying on 27 VI 1967
		3 VII 1967	Manglutan	Heavy mortality, & foul smell emitted from dead snails	
3.	29 VI 1967	3 VII 1967	Maymyo	Population much less	No rain soon after spraying on 27 VI 1967

in spreading the disease in the field population of two of these localities (Table 2). At Humphriganj, spraying was followed by heavy showers which probably did not give a chance to the causative organism of the disease to become established there.

MEAD (1956) has reported high incidence (35 to 68%) of disease in snails, but of low gastropod host specificity, meaning thereby that the disease of one species of snail may cause the disease in another species of snail. BOYCOTT & OLDHAM (1938) have reported the disease of *Helix aspersa* MÜLLER, 1776, to be contagious. MUMA (1954) has reported a disease in the tree snail *Drymaeus dormani* (BINNEY, 1857) and considers it to be of "possible bacterial origin." The reproductive potential of the introduced predators is very low, which is to some extent a disadvantage. Whereas in the case of disease it is not so. MEAD (1955) says that the reproductive capacity of disease is so great (unlike that of predators) that it can produce a catastrophic effect quickly upon the snail population. Present investigations go to show that the disease can be a potential agent in the control of snails; and one way of spreading disease in the field population of snails is to spray aqueous extract of diseased snails over the field population.

## SUMMARY

Disease of the giant African snail has now been detected in the culture as well as in the field population of this species on the Andamans.

Aqueous extract of diseased snails, when sprayed over healthy populations of the giant African snail, is capable of spreading the disease in them and finally causing mortality in about a week.

## ACKNOWLEDGMENTS

The authors wish to express their gratitude to Drs. S. Pradhan and N. C. Pant, Head of the Division and Professor of Entomology, respectively, for the facilities extended and the interest taken in the progress of the work. The authors are also grateful to the Director of Agriculture, Port Blair, and his staff, more especially Sri Bhagat Singh, for the active cooperation and assistance given to the authors at Port Blair.

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# The Egg Mass and Veligers of *Limacina helicina* PHIPPS

BY

MADHU A. PARANJAPE

Department of Oceanography, University of Washington  
Seattle, Washington 98105

(2 Text figures)

## INTRODUCTION

IN THE SUMMER OF 1966, while at the Friday Harbor Laboratories, Friday Harbor, Washington, I had an opportunity to observe the spawn and the veligers of an euthecosomatous pteropod, *Limacina helicina* (PHIPPS, 1774), in the laboratory. In view of the widespread occurrence of this genus throughout the world oceans, and in particular of this species in the polar and subpolar seas, it is rather surprising that there should be so little information on the breeding of these animals. More than 100 years ago, VAN BENEDEN (1839) described the structure of the reproductive system of *L. arctica* (*L. helicina*) and PELSENEER (1888) gave a detailed account of the morphology and anatomy of this species. MASSY (1920) observed many spawning specimens in the material collected in the Antarctic Ocean. She described the spawn-mass as a transparent, glutinous material connecting many white, oblong bodies, each of which averaged  $132\mu$  by  $88\mu$ . Besides this brief note, there are apparently no other observations on the spawn and veligers of this species. Thus, the present observations are of some interest.

McGOWAN (1963), in an extensive study of the distribution of *Limacina helicina* in the subarctic North Pacific, recognized two morphologically dissimilar, well-defined varieties: Variety A restricted to the Northwest Pacific, and Variety B limited to the Northeast Pacific. Where the boundaries of the distributions of these two varieties meet, intergrades AB were found. The present observations were made on Variety B.

## MATERIALS AND METHODS

The animals were collected with a 1.5 m diameter ring-net, in Saanich Inlet, British Columbia, Canada. The net was towed vertically from 100 m to the surface at night and the contents of the net were poured and diluted in several polyethylene trays. The animals were sorted out

immediately and were placed in 32-oz glass jars with screw caps, which were immersed in tanks with running sea water. In the laboratory, the animals were maintained in similar containers with unfiltered sea water to which a mixture of *Platymonas* sp. and *Skeletonema costatum* (GREVILLE) CLEVE, 1878 was added. The water was changed once every two days. The temperature of the water was about  $13^{\circ}\text{C}$  ( $\pm 2^{\circ}\text{C}$ ).

After two days in the laboratory, the majority of the animals spawned, perhaps in response to the higher temperature of the laboratory sea water. Copulation and the actual act of spawning were not observed. Most animals released egg ribbons which were found floating in the containers. In few animals, the egg ribbons were still attached to the body and the animals appeared to be having considerable difficulty in swimming. Instead of smooth, swift strokes of the wings, very awkward flapping movement was observed. In such cases, the egg ribbons were carefully removed from the animals. Few animals spawned again after about 20 days. The egg ribbons were observed under the microscope and their linear dimensions and the total number of eggs were estimated. The egg ribbons were then transferred to 6-oz finger bowls containing glass-fiber-filtered sea water. Thirty mg of streptomycin sulfate per liter was added to the water to control the bacterial growth. The finger bowls were placed on the water table with running sea water.

After the eggs had hatched, the veliger larvae were divided into two groups. One group was given unfiltered sea water, while the other group was maintained in the filtered sea water, supplemented with *Platymonas* sp. Periodically, a few larvae were removed from each group and were anesthetized partially with 1% chlorotone or 1% magnesium sulphate, on a depression slide. Drawings

<sup>1</sup> Contribution No. 445 from the Department of Oceanography, University of Washington, Seattle, Washington 98105

were made with the aid of either a Whipple disc or a camera lucida.

## OBSERVATIONS

### Adults:

Most animals were healthy for about 22 to 28 days in the laboratory. The animals actively swam up to the surface of the water in a broad spiral path and passively sank to the bottom, by a method very similar to that of *Limacina retroversa* FLEMING, 1823 (MORTON, 1954). Healthy specimens were almost transparent except for the deep-brown gonads. Unhealthy specimens soon acquired a dark-brown color around the edges of the wings and the visceral mass, became inactive, and died.

The genus *Limacina* is known to be a filter-feeder (MORTON, 1954). The gut contents of the specimens preserved in the field showed a few remains of diatoms, *Skeletonema costatum*, *Chaetoceros* spp., and *Thalassiosira* spp.; but dinoflagellates *Prorocentrum* sp., *Oxytoxum* sp., *Gymnodinium* sp., *Ceratium* sp., and tintinnids were most abundant. Unfortunately, phytoplankton samples from the Saanich Inlet, at the time of collection of animals, were not taken. Therefore, it is not known whether the dominance of dinoflagellates in the food was because of their abundance in nature or was due to selective feeding. *Skeletonema costatum* was most abundant in the guts of animals fed in the laboratory. In any case, the second spawning indicates that the animals were getting adequate food in the laboratory.

### Spawn:

The eggs of *Limacina helicina* were embedded in a thin, gelatinous ribbon, 3-4 mm long and 1-2 mm wide. The matrix was colorless and transparent but the eggs were slightly yellow, and were fairly closely spaced. The egg diameter was 95-100 $\mu$  in the longest dimension, while the diameter of the ovum was 75 $\mu$ . Because of the transparency and thinness of the ribbon, it was possible to estimate the egg number fairly accurately. Five complete egg ribbons and 4 egg-ribbon fragments were measured, their areas were estimated and the total number of eggs was counted. The mean egg-number per mm<sup>2</sup> was 80 and the total egg-number per spawn was 500 to 700 (Table 1). The second spawn contained the same number of eggs.

FOL (1875) has described the spawns of several species of pteropods. The eggs are generally embedded in a

Table 1

Egg-Mass of *Limacina helicina* PHIPPS

Length (mm)	Width (mm)	Total Area (mm <sup>2</sup> )	Eggs/mm <sup>2</sup>	Total Number of Eggs
3.72	2.05	7.61	80.3	611
4.09	2.08	8.52	83.1	708
3.42	1.71	5.86	79.4	465
3.59	1.51	5.41	92.1	498
3.66	1.79	6.54	82.8	542
2.33*	1.86	4.32	76.1	
3.06*	1.24	3.80	88.8	
2.34*	2.05	4.80	73.4	
2.46*	1.69	4.15	78.0	
Averages:			81.5	564.8

\* Fragments of the egg-mass.

gelatinous, transparent ribbon, or in a beaded string, or in a pea-pod-shaped case. The length of the egg ribbon varies from 2 to 10-50 mm (in *Cavolinia tridentata* (FORSKÅL, 1773)), while 20 to 725 eggs are produced with each spawn. A small number of eggs per spawn is usually associated with large-sized eggs. *Limacina retroversa* produces a 2 mm-long egg ribbon containing approximately 300 eggs (calculated from figure 1 in LEBOUR, 1932). Most pteropods have a pelagic larval stage in the life history, but *L. helicoides* JEFFREYS, 1877 is known to be a viviparous species (BONNEVIE, 1913).

Microscopic examination of the crushed gonadal tissues of *Limacina helicina* showed ova of various diameters. This observation and the second spawning, 20 days after the first, suggest that this species apparently does not spawn out after a short period of intensive reproductive activity. HSAIO (1939) observed that *L. retroversa* lays few eggs at a time and the female reproductive cells of various ages are found in the ovotestis of the animal. FOL (1875) also noted such a protracted spawning in other species of pteropods.

### Development:

No effort was made to study the details of the embryogenesis. FOL's (1875) information on the embryogenesis and organogenesis of pteropods has been summarized recently by RAVEN (1958).

The embryos began developing immediately (Figure 1 a, 1 b, 1 c). Toward the end of the first day, they started actively rotating inside the egg membrane. Unlike *Lima-*

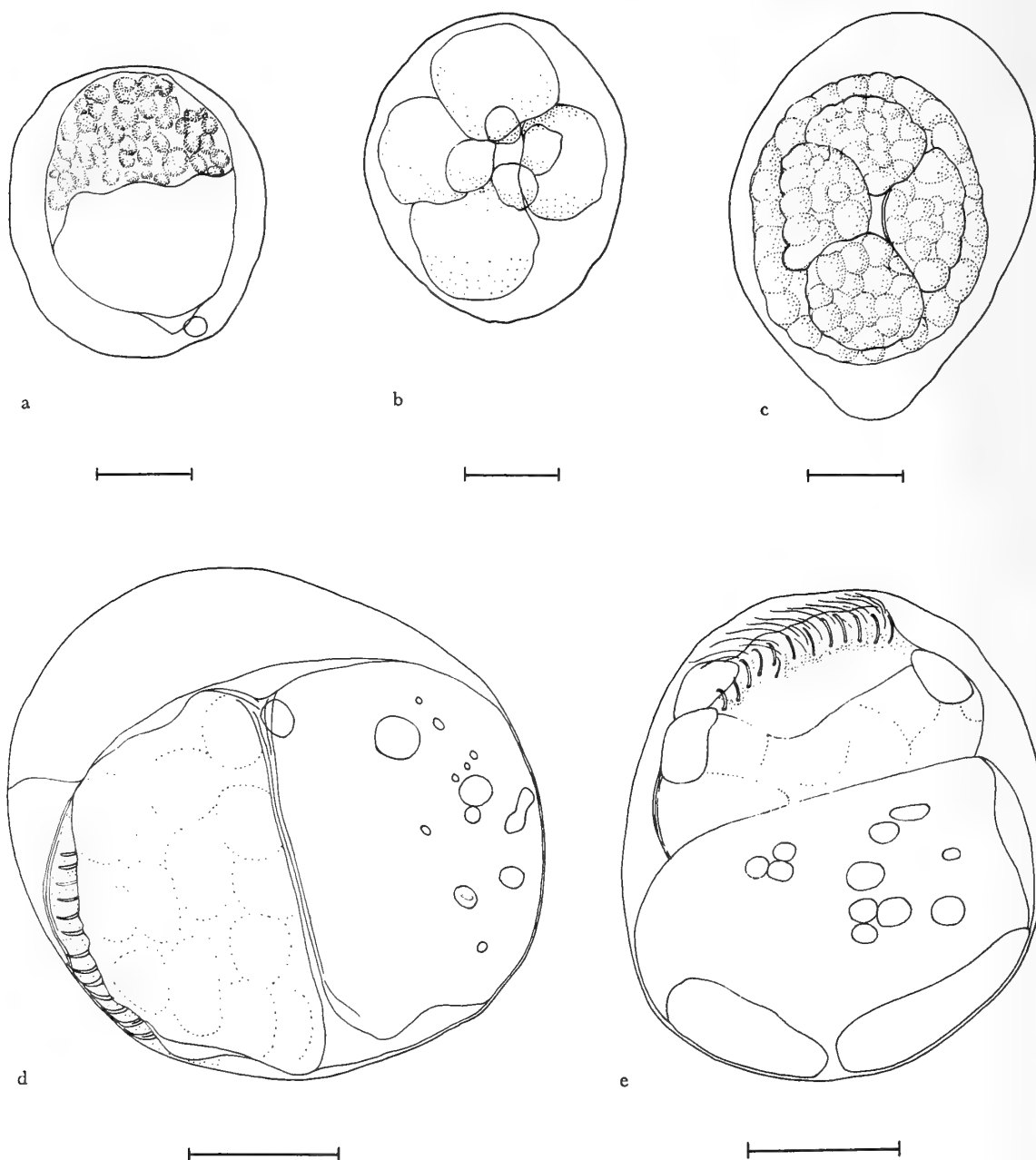


Figure 1

a, b, c: Stages in the development of the egg.  
d, e: Egg, just before hatching.  
Scale bar is 25  $\mu$

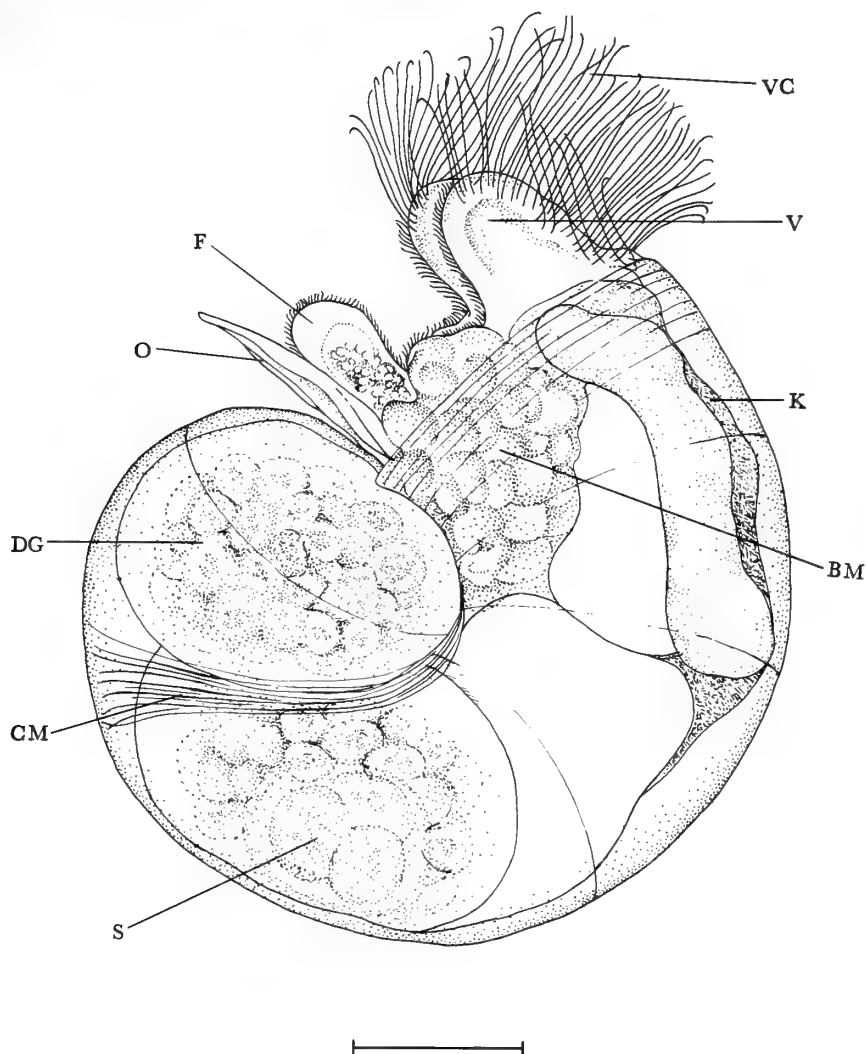


Figure 2

Seven-day-old veliger larva.

Scale bar is  $25\mu$ 

BM - Buccal Mass	CM - Columellar Muscles	F - Foot
K - Kidney	O - Operculum	S - Stomach
	VM - Velar Cilia	V - Velum

*cina retroversa* (LEBOUR, 1932), a cap-like, symmetrical and smooth shell developed before hatching (Figure 1 d, 1 e). Hatching occurred at the end of the second day. The newly hatched veliger larvae were about  $75\mu$  in diameter, with a bilobed velum, a small tongue-shaped, ciliated foot, and a thin, long, transparent operculum.

The larvae were very active and soon after hatching congregated near the water surface or on the lighted side of the container. The apical mass contained all the internal organs. By the fourth day their shell diameter increased to about  $105\mu$  and the internal organs were clearly visible. By the seventh or eighth day, the shell

became slightly purple, and faint horizontal striations could be recognized under proper illumination. Besides an increase in size, no basic changes in the internal organs were apparent. Figure 2 shows the darkly pigmented kidney and some parts of the digestive system that were recognizable. Larvae attained a mean diameter of  $200\mu$  by the 30<sup>th</sup> day. The foot then had enlarged, and cilia of the velum had become stronger and longer. The operculum was still present, and larvae were still positively phototactic. When the veliger of *L. retroversa* becomes 0.32 mm in diameter, from the sides of the foot, two lappets develop, which grow to form the wings of the adult. As these lappets grow in size, the velum and the foot diminish (LEBOUR, 1932). No such signs of metamorphosis were seen even after 30 days in *L. helicina*. For lack of time, the experiment was terminated at the end of 30 days.

There was no difference in the growth of larvae placed in unfiltered sea water dominated by *Skeletonema costatum*, and of those grown in the filtered sea water supplemented with *Platymonas* sp. Larvae at all stages fed well and the food cells could be easily seen in the alimentary canal. An effort was made to induce metamorphosis by subjecting the larvae to a sudden temperature change. On the 25<sup>th</sup> day, the temperature of one batch of larvae was raised to 18°C for 12 hours and that of another was dropped to 4°C for the same length of time. All the larvae survived the temperature change but the process of metamorphosis was not initiated. Prior to or after the temperature change, no larval shell showed any signs of vertical striations, which are characteristic of *L. helicina* Variety A (McGOWAN, 1963).

### SUMMARY

The euthecosomatous pteropod *Limacina helicina* produces a 3 - 4 mm long egg ribbon containing 500 - 700 eggs. The adults spawn more than once and apparently their reproductive activity is not limited to a short period. Development of veliger larvae up to 30 days is described and some observations on the food of the adult animals are recorded.

### ACKNOWLEDGMENT

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# Marine Fouling Organisms in Monterey Harbor

BY

E. C. HADERLIE

Department of Meteorology and Oceanography  
Naval Postgraduate School, Monterey, California 93940

(Plate 49; 3 Text figures)

## INTRODUCTION

THE PRESENCE of fouling and boring organisms in a harbor is not only of interest to the marine biologist but is of considerable economic importance to harbor engineers and maintenance personnel and to boat owners. On the Pacific Coast of North America relatively few published studies on fouling organisms have been made. These include investigations in Washington at Admiralty Inlet (DE PALMA, 1966) and Friday Harbor (JOHNSON & MILLER, 1935) and in California at Oakland (GRAHAM & GAY, 1945), Newport Harbor (SCHEER, 1945) and several studies in the La Jolla-San Diego area (COE, 1932; COE & ALLEN, 1937; ALEEM, 1957). The classic study of boring organisms on the Pacific Coast was published by KOFOED & MILLER (1927).

Until recently no systematic investigation of marine fouling and boring organisms had been made in Monterey Bay, California. MOMMSEN (1966) and MILLER (1966) carried out two short term studies in Monterey Harbor, and the present paper presents the results of a full year's subsequent observations in the same area. The object of the study was to obtain information concerning the kinds of organisms that settle on or burrow into test panels exposed in the water at various depths, to learn something of the season of attachment or settling, to note any correlation between settling of organisms and the temperature or salinity or both of the water, to determine choice of substrate for individual organisms, to measure the rate of growth of the dominant forms and to study seasonal progression over the year. Other workers have found great variability from year to year in the results obtained from such studies, and the present investigation is planned to continue for several years. This contribution is therefore to be viewed as an interim report on the first year of study. Additional systematic observations are being made simultaneously at various places in open water in Monterey Bay down to depths of 100 feet in order to compare

results obtained with those from the harbor. These studies will be reported in due time.

The author wishes to acknowledge the following colleagues for help in identification of various fouling organisms: Dr. E. N. Kozloff (Suctorians), Dr. Z. M. Arnold and Mr. Jack Gougé (Foraminiferans), Mr. G. F. Kelso (juvenile barnacles), Dr. I. A. Abbott (Algae) and Dr. D. P. Abbott (Ascidians). Mr. J. R. Lance assisted in resolving nomenclatural problems with opisthobranchs. Acknowledgment is also due my wife, Mrs. A. E. Haderlie, for assistance in the laboratory work, and to the Office of Naval Research for financial support.

## AREA OF STUDY

The site chosen for this study was near the outer end of Monterey Municipal Wharf No. 2, about 1000 m from the shore (Figure 1). This wharf was constructed in 1926 and is supported by concrete piles about 8 to 10 feet apart and has rows of creosoted wooden fender piles along each side. All of the piles are covered with a luxuriant growth of attached organisms dominated by acorn barnacles [*Balanus nubilus* DARWIN, 1854; *B. glandula* DARWIN, 1854; *B. crenatus* BRUGUIÈRE, 1789; *B. tintinnabulum* (LINNAEUS, 1758)]; anemones [*Metridium senile* (LINNAEUS, 1767); *Anthopleura xanthogrammica* (BRANDT, 1835); *Corynactis californica* CARLGREN, 1936]; bay mussels [*Mytilus edulis* LINNAEUS, 1758]; and numerous hydroids, bryozoans, polychaetes and tunicates. The depth of the water at the test site is about 21 feet at mean low tide. The maximum tidal fluctuation is 8 feet. The test site is at the outer edge of the harbor and pollution is not excessive; the water is often so clear that the sandy bottom can be seen easily. Throughout the period of study surface water temperature was recorded and salinity determinations were made every two weeks (Figure 2). Most of the test panels were exposed under the eastern edge of the wharf. The water in this

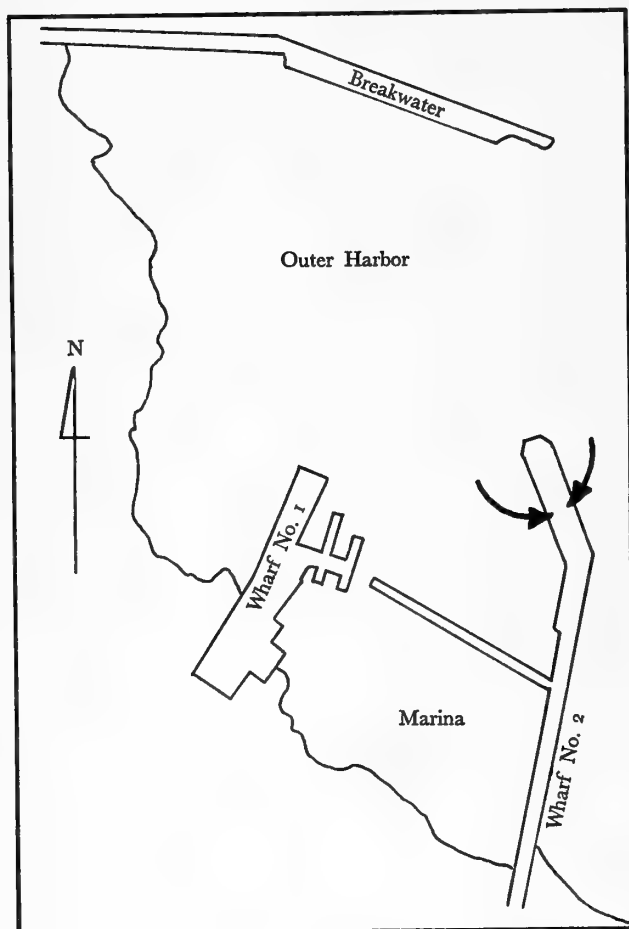


Figure 1

Map of Monterey Harbor, showing test sites under Municipal Wharf No. 2 (test sites indicated by arrows)

area receives very little direct sunlight and then only in the morning. One group of panels, to test for the effect of more light, was placed on the western edge of the wharf where the water receives direct sunlight for several hours in the afternoon.

## METHODS

In their short term studies of fouling organisms in Monterey Harbor, both MOMMSEN (1966) and MILLER (1966) tried a variety of test panels such as glass, plywood, stainless steel, masonite, fiberglass, and aluminum coated with Teflon. They both found that  $\frac{1}{4}$  inch douglas fir plywood was the best all-round collector, and this

material had the added advantage of collecting wood-boring organisms. In the present study standardized 8 inch by 10 inch panels of  $\frac{1}{4}$  inch marine grade douglas fir plywood were used as the primary collecting surfaces. Some workers (POMERAT & WEISS, 1946) have reported that asbestos board was the most promising material for maximum attachment of foulers. To test and compare asbestos board with wood in Monterey Harbor one set of collecting panels consisted of asbestos board of the same size as the plywood panels with one smooth and one roughened side (Johns-Manville Colorlith).

The collecting panels were supported vertically in racks similar to those employed by COE & ALLEN (1937) for the last 3 years of their study. All of the submerged racks were constructed of stainless steel (see Plate 49) and each held six 8 inch by 10 inch panels spaced at 3 inch intervals. One rack designed to float on the surface regardless of tidal level was made of  $\frac{3}{4}$  inch redwood slats. All racks were supported by a bridle and were held in position by  $\frac{3}{32}$  inch stainless steel bathythermograph wire. The racks were free to swing and rotate in the slight tidal currents found at the site.

A total of six racks was employed in this study. Five of the racks contained plywood panels, one contained asbestos board; they were positioned as follows:

- I. Floating rack. Constructed of wood and tethered with counterweights so that it floated with the top edge of the plywood collecting panels at the water's surface.
- II. Intertidal rack. Positioned about 4 feet above the lowest low tide level. The plywood panels in this rack were submerged approximately one half the time and exposed to air the other half.
- III. Shallow rack. Located 1 foot below lowest tide level; plywood panels always submerged.
- IV. Deep rack. Positioned 14 feet below lowest tide level and about 7 feet off the bottom. Plywood panels.
- V. Deep asbestos rack. This rack contained the asbestos board panels and was positioned at the same depth and close to the "deep rack" containing plywood panels.
- VI. Lighted rack. This rack of plywood panels was positioned 1 foot below lowest tide level on the western side of the wharf where the panels were exposed to afternoon sunlight.

The period covered by this study was from October 1, 1966 to October 1, 1967. Of the six panels in each of the racks, there were four that were left in place for 3 months (Panel 3P), 6 months (Panel 6P), 9 months (Panel 9P) and 12 months (Panel 12P) respectively. These were designated as Long Term panels. The re-

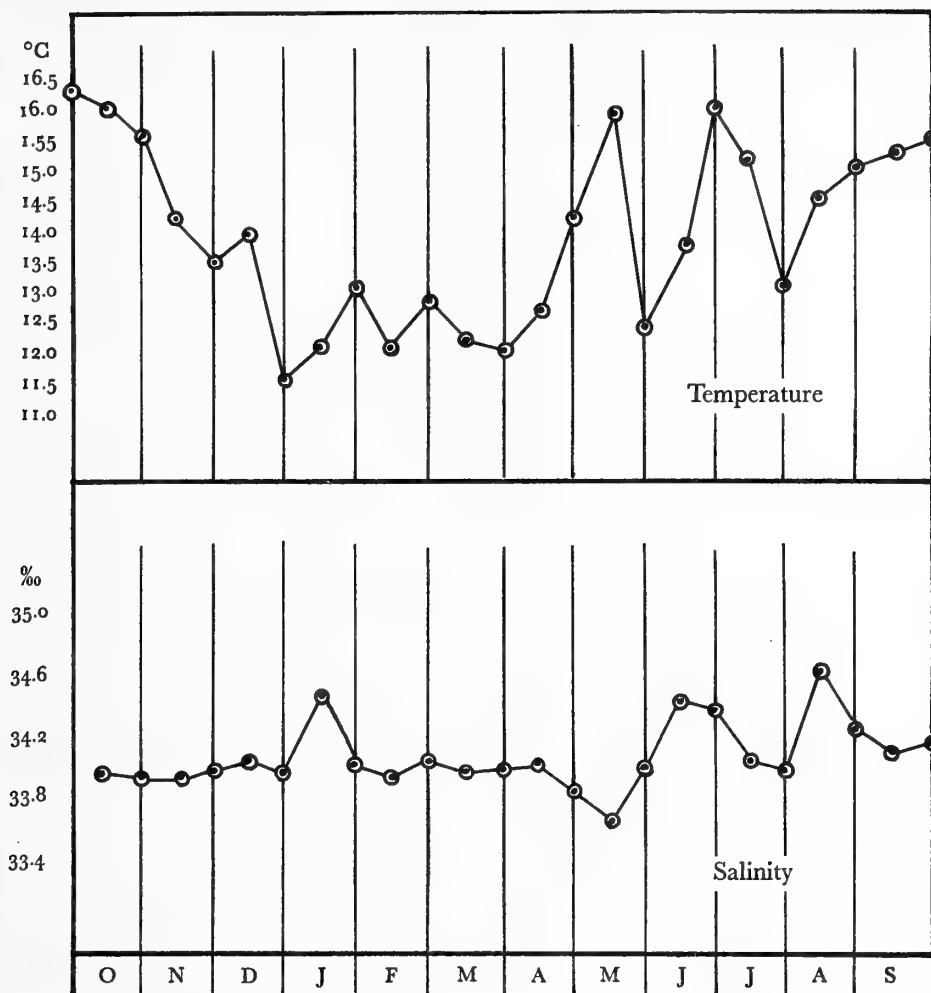


Figure 2

Biweekly morning temperatures and salinities at test site for the year October 1, 1966 to October 1, 1967

maintaining two panels in each rack were designated Short Term panels (T panels): one was put in on the first of each month and retrieved for study on the first of the next month; the second was put in on the fifteenth of each month and retrieved a month later. These short term panels therefore overlapped one another and made possible more exact determination of settling time. A total of 162 panels were exposed and examined during the year. Two of the panels from the 3 month series were lost. The length of exposure of the various panels in each rack is shown diagrammatically in Figure 3.

In many of the previous studies on fouling organisms on this coast, investigators have found it expedient to

scrape the fouling organisms off the panels and preserve the entire lot in formalin or alcohol for later sorting and identification. In a preliminary pilot study carried out two years ago in Monterey Harbor this technique proved to make identification very difficult and often impossible, especially for small, delicate, recently-settled forms. Throughout this study, therefore, the retrieved panels were placed in tubs of sea water or in aquaria with running sea water immediately after removal from the racks and were examined as soon as possible, usually within 3 hours of being removed from the sea. For examination each panel was placed in a pan of sea water and the entire surface surveyed with a binocular stereo-

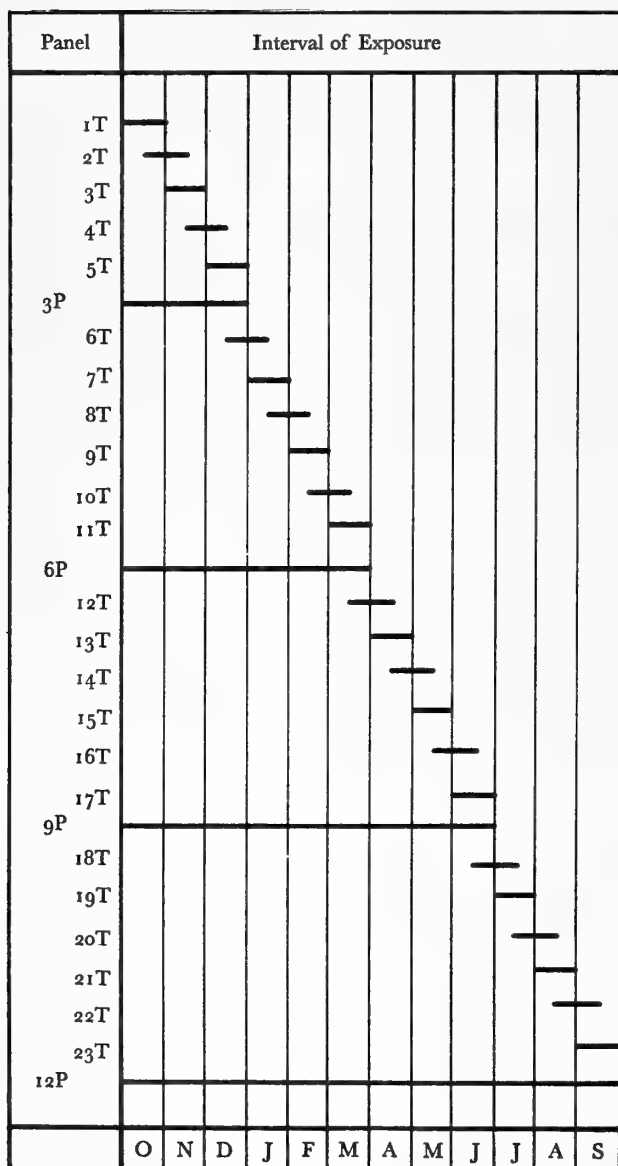


Figure 3

Diagram illustrating period of exposure for test panels  
from October 1, 1966 to October 1, 1967

T = Short term panels

P = Long term panels

scopic microscope (7x to 30x magnification). This made it possible to see and record very small living organisms such as some of the protozoans and newly settled stages of bryozoans and barnacles. This technique not only made identification easier but made it possible to observe

the behavior of the organisms, determine where on the panel they tended to settle, their size, relative abundance, what their associates were, etc. Proper identification of the fouling organisms, especially the very young stages, was constantly a problem, but with experience and the help of specialists it became easier. In some cases panels with juvenile organisms of questionable identity were kept in aquaria or were returned to the original racks for additional periods during which time the organisms in question matured enough to make identification possible. Representative organisms were then removed from the panel and preserved for later study and reference. The entire wooden panel of the short term series was air dried and retained for reference. In the case of the panels in the long term series that had been in the water from three months up to a full year, a careful study was made to determine which organisms were dominant, their size and shape and the percentage of the surface each species covered. After examination, one of the flat surfaces of each of these panels was scraped clean of attached organisms and the scrapings were oven dried at 100° C until the weight was constant. The results are expressed as grams of dry weight tissue per panel side (80 square inches or 512 $\frac{3}{4}$  cm<sup>2</sup>). This provides a rough statistical measure of concentration and an index to productivity of the environment for the specific time period of exposure (see bottom line Table 3). In many cases, however, the older panels had obviously suffered loss of part of the fouling growth due to periodic buffeting of the racks against piles when wave action was severe. The panel with the remaining organisms intact on one side was air dried and saved for reference.

## THE FOULING COMMUNITY

### I. Discussion of Organisms Settling on Short Term Panels

During the year of observation a total of 70 different kinds of organisms, identified at least to genus, were found on the short term panels. Some organisms were found to have settled during every month of the year, indicating either a continuous breeding cycle or larval forms that can live free for some time before settling. Others settled only seasonally. The truly sessile organisms (primary foulers) received the most attention and a serious attempt was made to identify to species all such forms, but many of the more easily identified motile organisms (secondary foulers) that were found on the panels, were also recorded. Numbers of diatoms, tiny flatworms, nematodes, small errant polychaetes, minute snails, mites, free-swimming copepods and crustacean

larval forms were often observed but few of these were identified.

Table 1 is an example of how the data were collected and recorded for one common fouling organism, *Balanus crenatus* BRUGUIÈRE, 1789. Similar tables were prepared for each of the 70 organisms. For bryozoans, hydroids, etc., numbers of discrete colonies were counted rather than individuals.

Table 1

The number of barnacles (*Balanus crenatus*) that settled on various panels throughout the year. A table similar to this was prepared for each of the 70 species encountered

Panel Number	Lighted Panel	Intertidal Panel	Floating Panel	Shallow Panel	Deep Panel	Asbestos Panel
1 - T		20				
2 - T		1	1			
3 - T						1
4 - T				1		2
5 - T			1	1	1	3
6 - T		1	1	2		
7 - T	1	3	1			
8 - T	1	2		1		4
9 - T		4				4
10 - T		30	150	100	160	6
11 - T	1	25	20	8	10	5
12 - T	2	100	10	5	5	
13 - T		3	50		2	
14 - T		4	12	10	2	
15 - T	1	20	40	3	1	1
16 - T		10	100	1	1	
17 - T	1	25	25		2	
18 - T		20	10			
19 - T		5	10			
20 - T	3	20	25	50	5	20
21 - T	2	20	20	100	4	1
22 - T	1	2	10	10		10
23 - T		6	15	10		
Total panels fouled:	9	20	18	14	11	11

The data from the entire observation period are summarized in Table 2. This table lists the identified organisms, the numbers of individual test panels where the organisms settled, and the period of the year when the organisms occupied the panels. Also indicated are those panels that carried the greatest number of individuals or colonies of organisms, and at the bottom of the table the number of species collected by each panel.

As can be seen from an examination of Table 2, the most common fouling organisms encountered on the short term panels were encrusting cheilostomate and cyclostomate bryozoans, calcareous serpulid worms, the acorn barnacle *Balanus crenatus*, foraminiferans, ciliates, the nestling clam *Hiatella arctica* and the opisthobranch *Hermisenda crassicornis*. The following discussion will briefly review the most common organisms of each of the major groups listed in Table 2.

#### Algae:

None of the short term panels ever had an extensive growth of algae. After one month in the water all panels usually had a slippery surface film that probably consisted of microorganisms too small to be seen, and on many of the panels in racks near the surface, chains of colonial diatoms were observed but not identified. On the rack suspended just below tide level on the western side of the wharf (the lighted rack) where afternoon light was greatest, it was expected that the panels would collect algae and during the summer months small sprigs of green and red algae were often found. *Ulva* sp., *Polysiphonia pacifica* and *Herposiphonia parva* were the only plants identified. In all cases the growth was very sparse. On one panel, numerous fans of the colonial diatom *Licmophora* sp. were observed.

#### Protozoa:

Three species of foraminiferans were observed on various panels. The most common by far was *Cornuspira lajollaensis*. It was found throughout the year on panels at all depths and positions, but was especially abundant on the intertidal and floating panels. The next most abundant protozoan was the large pink or reddish ciliate *Folliculina* sp. which again was found throughout the year and often in such numbers as to make the panel look dark to the naked eye. The suctorian *Ephelota gemmipara* was sometimes seen as a small forest on the surface of the panels and especially as a fuzzy growth on the clam *Hiatella arctica* and on hydroids. Ciliated swimmers were seen leaving *Ephelota* during February. The stalked colonial ciliate *Zoothamnium* sp. was fairly common and was most clearly seen on the roughened edge of the panels.

#### Porifera:

The only sponge that was common on the short term panels was *Leucosolenia cleonor*. In the time available this sponge never was able to form dense masses of anastomosing tubes, but consisted of a few short tubes

Table 2

List of Species, and of Panels where Organisms Settled in Short Term Series

Species	Number of test panels on which organisms settled <sup>1</sup>						Total panels occupied	Interval test panels were occupied (October, 1 1966 - October 1, 1967)
	L	I	F	S	D	A		
<b>Algae:</b>								
<i>Licmophora</i> sp.	1 <sup>2</sup>	0	0	0	0	0	1	September
<i>Ulva</i> sp.	8	0	0	0	0	0	8	January - October
<i>Polysiphonia pacifica</i> HOLLENBERG, 1942	4	0	0	0	0	0	4	July - September
<i>Herposiphonia parva</i> HOLLENBERG, 1943	4	0	0	0	0	0	4	July - September
<b>Protozoa:</b>								
<i>Cornuspira lajollaensis</i> UCHIO, 1960	11	18	11	14	14	13	81	October - October
<i>Rosalina columbiensis</i> (CUSHMAN, 1925)	2	2	1	5	3	1	14	June - October
<i>Spirillina revertens</i> (RHUMBLER, 1906)	2	0	2	0	1	0	5	July - September
<i>Zoothamnium</i> sp.	7	4	1	8	4	3	27	October - October
<i>Folliculina</i> sp.	15	4	3	16	21	9	68	October - October
<i>Vorticella</i> sp.	0	0	0	0	1	0	1	September
<i>Ephelota gemmipara</i> (HARTWIG, 1876)	1	5	5	5	3	2	21	October - October
<b>Porifera:</b>								
<i>Leuconia heathi</i> (URBAN, 1905)	0	1	0	2	2	1	6	January - July
<i>Leucosolenia eleanor</i> URBAN, 1905	5	7	8	7	8	6	41	February - October
<b>Coelenterata:</b>								
<i>Obelia</i> spp.	9	15	9	0	1	1	35	October - October
<i>Hydractinia</i> sp.	0	1	1	0	0	0	2	May
<i>Syncoryne mirabilis</i> (AGASSIZ, 1862)	5	7	8	3	0	1	24	November - October
<i>Campanularia</i> sp.	1	0	0	0	0	0	1	July
<i>Anthopleura</i> sp.	0	0	0	1	1	0	2	November - December
<b>Platyhelminthes:</b>								
<i>Stylochoplana gracilis</i> HEATH & MCGREGOR, 1912	7	7	4	5	9	12	44	October - October
<i>Notoplana acticola</i> (BOONE, 1929)	0	2	1	0	1	6	10	February - October
<i>Thysanozoon californicum</i> HYMAN, 1953	1	0	1	1	1	0	4	March; May - June; September
<i>Stylochus tripartitis</i> HYMAN, 1953	0	0	2	0	0	0	2	June
<i>Stylochus</i> sp.	1	0	1	0	0	0	2	March; July
<b>Nemertea:</b>								
<i>Emplectonema gracile</i> (JOHNSTON, 1837)	0	0	3	0	0	0	3	March - May
<b>Ectoprocta (Bryozoa):</b>								
<i>Bowerbankia gracilis</i> O'DONOGHUE, 1926	6	16	12	7	6	9	56	January - October
<i>Filicrisia franciscana</i> (ROBERTSON, 1910)	4	1	1	4	1	4	15	May - October
<i>Crisia</i> sp.	1	0	0	0	0	1	2	June - August
<i>Crisulipora occidentalis</i> ROBERTSON, 1910	1	1	1	10	7	2	22	November - October
<i>Tubulipora pacifica</i> ROBERTSON, 1910	17	2	2	22	20	20	83	October - October
<i>Bugula neritina</i> (LINNAEUS, 1758)	8	4	1	16	11	9	49	January - October
<i>Bugula californica</i> ROBERTSON, 1905	4	0	0	3	4	6	17	November - January; May - October
<i>Hippothoa hyalina</i> (LINNAEUS, 1767)	21	10	10	21	22	22	106	October - October
<i>Lyrula hippocrepis</i> (HINCKS, 1882)	13	8	8	12	5	19	65	November - October
<i>Scrupocellaria californica</i> TRASK, 1857	0	0	0	0	0	2	2	May
<i>Scruparia ambigua</i> (D'ORBIGNY, 1841)	17	2	1	11	11	12	54	October - October
<i>Holoporella brunnea</i> (HINCKS, 1884)	13	7	4	19	14	19	76	November - October
<b>Entoprocta:</b>								
<i>Barentsia gracilis</i> (LOMAX, 1886)	0	0	0	0	0	1	1	January
<b>Annelida:</b>								
<i>Nereis</i> sp.	0	1	0	0	0	0	1	August
<i>Platynereis agassizi</i> (EHLERS, 1868)	0	0	0	1	0	4	5	April - July
<i>Pectinaria californiensis</i> HARTMAN, 1941	1	0	0	0	0	0	1	August
<i>Halosydna brevisetosa</i> KINBERG, 1855	0	1	1	0	2	1	5	March; August - October

Table 2 [Continued]

Species	Number of test panels on which organisms settled <sup>1</sup>						Total panels occupied	Interval test panels were occupied (October, 1 1966 - October 1, 1967)
	L	I	F	S	D	A		
<b>Annelida (continued)</b>								
<i>Sabellaria cementarium</i> MOORE, 1906	0	0	0	0	1	0	1	March
<i>Spirorbis spirillum</i> (LINNAEUS, 1758)	21	8	9	22	23	22	105	October - October
<i>Serpula</i> sp.	7	7	3	13	13	16	59	October - October
<i>Polydora brachycephala</i> HARTMAN, 1936	3	1	1	0	1	5	11	February - August
<i>Thelepus</i> sp.	0	0	0	0	0	1	1	August
<b>Arthropoda:</b>								
<i>Balanus crenatus</i> BRUGUIÈRE, 1789	9	20	18	14	11	11	83	October - October
<i>Balanus glandula</i> DARWIN, 1854	0	1	1	0	0	0	2	June; August
<i>Chthamalus</i> sp.	1	1	1	1	0	0	4	July - September
<i>Idothea</i> sp.	0	1	0	0	1	0	2	February; May
<i>Limnoria quadripunctata</i> HOLTHUIS, 1949	8	13	10	19	10	0	60	October - October
<i>Caprella</i> sp.	5	5	2	6	3	5	26	November; February; May - October
<i>Corophium insidiosum</i> CRAWFORD, 1937	0	0	5	0	0	1	6	March - July; August
<b>Mollusca:</b>								
<i>Pododesmus cepio</i> (GRAY, 1850)	2	1	0	5	3	1	12	October; July - September
<i>Mytilus edulis</i> LINNAEUS, 1758	2	5	9	1	2	0	19	October; January; July - September
<i>Pecten</i> sp.	1	0	0	0	0	2	3	July - September
<i>Hiatella arctica</i> (LINNAEUS, 1771)	6	12	12	11	13	9	63	October - October
<i>Bankia setacea</i> (TRYON, 1863)	0	0	0	2	0	0	2	February - April
<i>Hermisenda crassicornis</i> (ESCHSCHOLTZ, 1831)	10	12	11	13	10	12	68	October - October
<i>Doto kya</i> MARCUS, 1961	0	0	1	0	0	0	1	May
<i>Dendronotus frondosus</i> (ASCANIUS, 1774)	0	3	3	1	0	1	8	January - July
<i>Acanthodoris brunnea</i> MACFARLAND, 1905	0	0	1	0	0	0	1	June
<i>Triopha grandis</i> MACFARLAND, 1905	2	0	0	2	0	0	4	December; February; April
<i>Cratena albocrusta</i> MACFARLAND, 1966	2	1	0	0	3	0	6	January; May; August
<i>Polycera atra</i> MACFARLAND, 1905	1	1	1	2	1	0	6	February - August
<i>Acmaea</i> sp.	0	3	1	0	0	0	4	March - July
<i>Mopalia</i> sp.	0	0	0	1	0	0	1	May
<b>Echinodermata:</b>								
<i>Strongylocentrotus</i> sp.	9	8	9	7	8	8	49	January
<i>Eupentacta quinquesemita</i> (SELENKA, 1867)	0	0	0	0	0	1	1	June
<i>Pisaster</i> sp.	1	0	0	1	2	2	6	June - September
Total species collected by each type panel:	46	41	44	39	41	41		

<sup>1</sup> Panel designations are as follows: L=Lighted Panel S=Shallow Panel  
I=Intertidal Panel D=Deep Panel  
F=Floating Panel A=Asbestos Panel

<sup>2</sup> Bold face figures indicate the group of panels with the greatest number of individuals or colonies

tightly pressed on the panel surface. A few small specimens of *Leuconia heathi* were occasionally observed, especially on the deep panels.

#### Coelenterata:

In most fouling studies, investigators have reported hydroids as among the most common organisms. This was not found to be true under the Monterey wharf. *Obelia* sp. was found throughout the year, but was usually a very sparse growth except for a few of the intertidal

panels where it formed a flourishing colony with stalks 2 cm high. Maximum growth was in May, and medusae were released at that time. The only other hydroid found in any significant number was *Syncoryne mirabilis* and it was found as a very sparse growth except on a few floating panels in June. Small anemones (*Anthopleura* sp.) were found on only two occasions on the short term panels. It is surprising that more anemones did not settle on the panels, for several species are found growing in great numbers on nearby piles.

### Platyhelminthes:

Flatworms were common secondary foulers on many of the panels, but some of the worms were so minute as to make identification impossible. The most consistent and conspicuous form was the small cuneate *Stylocho-plana gracilis* which was present all year. It was abundant on the deep panels, especially those of asbestos board, and was always seen gliding in and among the bryozoans and barnacles. An interesting flatworm encountered only rarely was *Thysanozoon californicum*. This small worm has a papillated dorsal surface and its color and texture often closely matched the bryozoan colonies (*Holoporella brunnea*) among which it lived.

### Nemertea:

Small specimens of *Emplectonema gracile* were found on two panels in the floating rack in March and April. This was the only nemertean found on the short term panels.

### Ectoprocta (Bryozoa):

During the period of this study, bryozoans clearly constituted the dominant fouling organisms on the short term panels in respect to numbers of species involved, number of panels fouled and numbers of individual colonies. The single species that was dominant on all the submerged panels throughout the year was *Hippothoa hyalina*. This organism forms a circular colony that is hyaline and appears as delicate silvery patches on test surfaces. On many of the shallow and deep panels there were hundreds of colonies up to 5.0mm in diameter on each side of the panel. Next in importance was *Tubulipora pacifica*. This cyclostomate bryozoan forms a colony that when small is a fan-shaped mat of calcareous tubes with the open ends pointing upward. On the short term panels these colonies never were more than 1-2mm in diameter, but on deep wooden and asbestos panels in June there were hundreds of colonies which made the test surface feel rough like sandpaper. *Tubulipora* was found on the floating and intertidal panels only in August and September, but on others it occurred throughout the year. Two other encrusting bryozoans that were a conspicuous part of the fouling community throughout most of the year were *Lyrula hippocrepis* and *Holoporella brunnea*. These colonies were often colored yellow or orange and after being on the panel one month or less were up to 4 or 5mm across. One large *Lyrula* colony, however, attained a diameter of 10mm in a month or less.

Erect bryozoans were less common on the short term

panels than the encrusting forms, yet many of these had formed small colonies. *Scruparia ambigua* was never abundant on any one panel, but it was found throughout the year on all submerged panels. The site of growth of *Scruparia* was most often on the roughened edge of the panel and it was never more than a few millimeters high. *Bowerbankia gracilis* was found from January through September and was represented on panels at all depths. The creeping stolons of *Bowerbankia* often gave rise to only a few zooecia, but in some cases on intertidal panels in February and again from May to July a thick furry coating was found. *Bugula neritina* is easily recognized by its purplish color, and was found as small sprigs from January to October. *Crisulipora occidentalis* was the only other bryozoan that occurred with any regularity. It was found throughout most of the year on many of the submerged panels, but was most common on the shallow ones.

### Entoprocta:

The only entoproct observed during the year of study was *Barentsia gracilis*; it was seen as a small colony only once on an asbestos panel in February.

### Annelida:

*Spirorbis spirillum* was second only to the bryozoan *Hippothoa hyalina* in number of panels fouled and it settled on the surfaces throughout the year. It was least common on the floating and intertidal panels, but was abundant on all of the submerged ones, both wood and asbestos. On some panels, over 50 tubes per side were not uncommon. Most of the tubes were tightly spiraled and averaged 0.5mm in diameter but some were up to 1.0mm. Both sinistral and dextral tubes in about equal numbers were represented. The twisted but not coiled tubes of another serpulid (*Serpula* sp.) were also found throughout the year, but these were less abundant than *Spirorbis*, both as individuals and in terms of number of panels settled on. The maximum growth of *Serpula* sp. in one month was up to 6mm in tube length. The only other annelid that occurred regularly was the tube-building *Polydora brachycephala*. The tubes built of silt and debris were fairly common, especially on the asbestos panels. Many tiny errant polychaetes were observed on nearly every test surface, but none of these were identified.

### Arthropoda:

As was to be expected, the dominant arthropod foulers were acorn barnacles. On the piles of the wharf *Balanus*

*glandula*, *B. crenatus*, *B. tintinnabulum* and *B. nubilis* are common, yet, except for a few specimens of *B. glandula* and *Chthamalus* sp., *B. crenatus* was the only barnacle that was found as a significant fouler on the test surfaces. Throughout the entire year and on panels at all depths, small specimens of *B. crenatus* could be found. Many were recently settled forms 0.1 mm across, but others were up to 2.5 mm after being on the panel one month or less. As a rule any one panel had only a few barnacles, but enough to show that *B. crenatus* settles throughout the year (see Table 1). The period of maximum settling was from mid-February through March. This was also found by MOMMSEN (1966) to be the period of maximum settling of *B. crenatus*. It is interesting to note that during late February and early March the maximum settling of up to 25 barnacles per square inch was on the floating, shallow and deep wooden panels, but in late March the maximum settling was on the intertidal panels. In late May and early June another period of intense settling of *B. crenatus* occurred on the floating panels and in late July and August a heavy settling on the shallow panels.

In a survey in the same area during the previous summer, MILLER (1966) found massive settling (up to 50 per square inch) of *Balanus crenatus* in late June and early July, and the deep panels were most heavily fouled. In contrast to this, the present study found practically no barnacles settling on the deep panels during late June and July, and only a few on the intertidal and floating panels. The explanation of this might be found in differences in water temperature. In MILLER's study the temperature fluctuated between 12.5° C and 14.0° C during this period, whereas in 1967 the temperature varied between 13.5° C and 15.8° C (Figure 2).

In terms of choice of color of substrate, no significant differences were found in the rate or season of settling of *Balanus crenatus* on the dark asbestos panels and the lighter wooden panels at 14 feet depth. On the upper panels subject to more light, however, it was found that the larvae tended to settle most abundantly on darker parts of the wood and on dark lines drawn on the wood.

As will be noted later, *Balanus tintinnabulum* settled on the long term panels and on the stainless steel racks, but this barnacle was never seen on the short term panels. Perhaps this species, like some other fouling organisms, requires the presence of living organisms on a surface before it will settle.

Other arthropods recorded on the short term panels were secondary foulers. Various copepods were found on practically every test surface, but none were identified. The skeleton shrimp, *Caprella* sp., and the tube-building amphipod *Corophium insidiosum* were occasionally present as was the isopod *Idothea* sp. Mites and crustacean

larvae were common and abundant and the wood boring gribble *Limnoria quadripunctata* was often seen crawling over the surface or in shallow burrows in the wood.

#### Mollusca:

The attached mollusk most often encountered on the short term panels was the nestling clam *Hiatella arctica*. This white, rectangular clam was found throughout the year on panels at all depths, but the greatest number of individuals was on the floating panels. Most of the animals were very small (2 mm and less) and were usually seen creeping over the test surface, but larger clams (10 mm and more) were often attached by byssal threads. The clams were most common in depressions in the wood surfaces.

Small numbers of the bay mussel, *Mytilus edulis*, were also found on wooden panels at all depths throughout most of the year. Most of these were small and mobile, but others were up to 10 mm long and attached. Never were there more than 4 or 5 animals on a panel. *Pododesmus cepio* was also found attached to or moving over the panels. These were invariably very small.

Opisthobranchs were encountered on the test surfaces throughout the year. By far the most common and abundant species was *Hermisenda crassicornis*. Each panel occupied normally carried from 1 to 5 animals, and egg masses of *Hermisenda* were found during every month of the year. *Dendronotus frondosus* was seen only on a few panels, but when seen it was very abundant. *Cratena albocrusta* and *Polycera atra*, although not seen often, were abundant on certain panels. Other opisthobranchs listed in Table 2 were found only rarely. Except for *Hermisenda crassicornis*, which appeared on panels regardless of what other organisms were present, most of the nudibranchs found were on panels which supported colonies of *Obelia* or other hydroids.

Other mollusks encountered on the temporary panels were gastropods of a variety of forms but invariably small and none were identified. Also found one or more times were tiny limpets (*Acmaea* sp.) and very small chitons (*Mopalia* sp.).

#### Echinodermata:

From January through September, small sea urchins (*Strongylocentrotus* sp.) averaging 0.5 mm in diameter were frequently encountered in small numbers on panels at all depths. Tiny asteroids (*Pisaster* sp.) appeared on a few panels from June to September and a single specimen of the sea cucumber *Eupentacta quinquesemita* was seen in June.

### Chordata (Tunicata):

As will be seen later, 3 species of tunicates settled on the long term panels and on the stainless steel and wooden racks. Yet, no tunicates were ever observed on the short term panels. It is possible that these animals are not pioneers in the fouling community, but settle only after the surface has been "prepared" by other organisms.

## II. Depth and Surface Preference

At the bottom of Table 2 is a summation of the total number of species of fouling and boring organisms collected by each category of test panel. There are only slight differences in the total number of species each collected. As has been pointed out in the above discussion of the organisms that settled on the short term panels, some definitely preferred one depth to another, but the preference varied from species to species. One of the purposes of this study was to determine the type of surface that would collect the maximum number of fouling organisms, and to get data relative to this problem, panels of 2 different materials (plywood and asbestos board) were submerged to identical depths in the same area to test their relative effectiveness as collectors. As can be seen from Table 2, there was no difference in the number of species collected by these different materials, and in settling most foulers did not seem to distinguish between the two. Some organisms, however (e. g. *Folliculina* sp.), seemed to prefer plywood to asbestos board, whereas the reverse was true for others (e. g. *Lyrula hippocrepis*). The asbestos board had one smooth and one rough surface but these differences had no effect on rate of settling of foulers except that there was a tendency for more barnacles (*Balanus crenatus*) to settle on the rough surface than on the smooth, and encrusting bryozoa seemed to prefer the smooth surface. These differences, however, were only slight.

## III. Discussion of Organisms

### Settling on Long Term Panels

Table 3 lists the fouling and boring organisms observed on the long term panels. As can be seen, the list is similar to that of the organisms on the short term panels (Table 2). It is a longer list, however, containing 81 kinds of organisms identified at least to genus, and several organisms were found in fair numbers on the long term panels that were never encountered on panels in the water for only one month. As SHEER (1945) and others have pointed out, this is to be expected, for many

organisms settle on surfaces only when these surfaces have been colonized by pioneering foulers.

The long term panels presented many difficulties in analysis. Very often one or two species of bryozoans, for example, were the dominant organisms at the time the panels were removed for study, and these had overgrown and completely smothered earlier populations of barnacles and serpulid worms. In the case of panels practically covered with a foliaceous growth of erect bryozoans, it was impossible to locate all the organisms living in and around the bryozoans. It was obvious that very often the growth of organisms had become so heavy on a panel that large slabs of fouling growth had broken off and the area was being recolonized by other forms. This explains why the weight of the fouling mass on a 9-month panel might be less than on one of 6 months (see Table 3, bottom). As before, each of the major groups and dominant organisms will be discussed briefly.

### Algae:

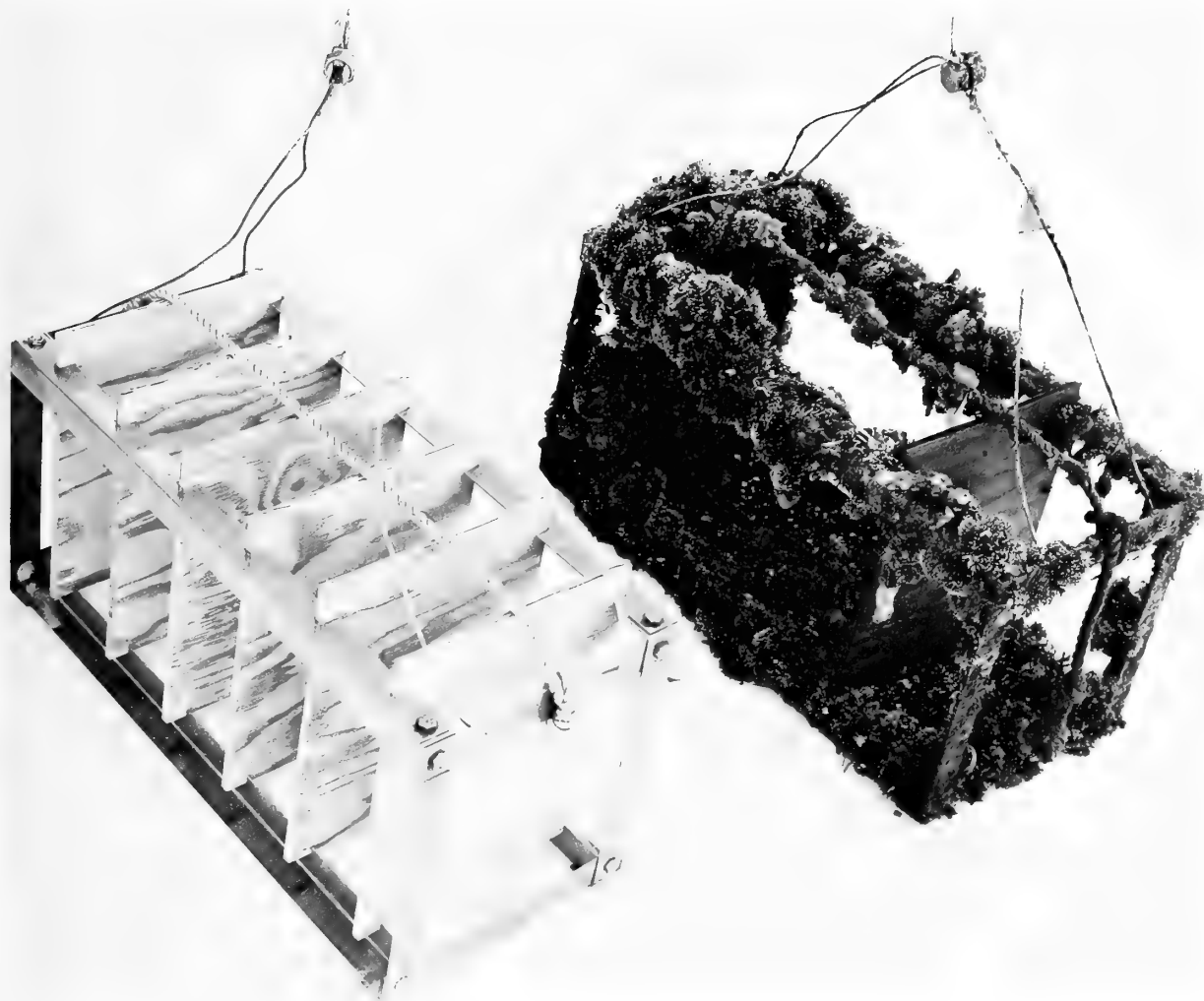
Five species of green and red algae were found on the long term panels in the lighted rack. Even after 12 months the growth of algae was very sparse and did not constitute a dominant part of the fouling mass. Diatoms were observed attached to bryozoans and other fouling animals but none of these were identified.

### Protozoa:

It was very difficult to detect protozoans in the mass of multicellular foulers, yet essentially the same forms were found as on the short term series. *Cornuspira lajollaensis* was the dominant foraminiferan, and on the 12-month floating panel was found in thousands. *Folliculina* sp. was the most commonly encountered ciliate.

### Porifera:

On the long term panels *Leucosolenia eleanor* appeared as large masses of anastomosing tubes, and was often covered with silt and debris. At one time or another it was found on panels at all depths and was also abundant on the floating and intertidal racks. *Leuconia heathi* was a common sponge on the submerged panels and racks but was not found on those in the intertidal or the floating series. On some of the 12-month panels single specimens of this sponge were often up to 8 cm long, but most were globular and about 3 cm in diameter. *Rhabdodermella nuttingi* was found only on 9-month and 12-month test surfaces. It was never abundant, and was found in small clumps, the individuals reaching a maximum length of 5 cm.



Photograph of test racks and panels

Left, rack and 6 panels in place ready for exposure. Right, deep rack following removal from water after 12 months exposure. The 12 month panel and the last temporary panel (23-T) still in place. Fouling growth primarily *Crisulipora occidentalis*.



**Coelenterata:**

The only consistent hydroid fouler on the long term panels was *Obelia* sp. It was most abundant on the intertidal panels, and on the deep asbestos panels. The anemone *Corynactis californica* was found in small numbers on one asbestos panel at 9 months and on one deep wood panel at 12 months and was found attached to the wood bottom plates of the intertidal, shallow and deep racks. This anemone is common on the wharf pilings, but was never encountered except in these few instances cited.

**Platyhelminthes:**

Essentially the same group of flatworms inhabited the long term and short term panels. Much larger worms, however, especially *Stylochus tripartitis*, were found on the long term surfaces, and in all cases the flatworms were more abundant on the older, more heavily fouled surfaces.

**Nemertea:**

The three species of nemerteans found on the long term series were few in number but large in size. One *Emplectonema gracile* attained a length of over 30 cm. These worms often occupied open burrows that had been excavated by *Limnoria*, or dead shells of barnacles.

**Ectoprocta (Bryozoa):**

The bryozoans again were the dominant organisms on all of the long term panels and on most of the racks. On the submerged panels and racks *Crisulipora occidentalis* was often so dominant as to make the surface appear to be covered with nothing else (see Plate 49). The thickness of the *Crisulipora* growth often exceeded 5 cm, and on the deep panels this growth made up more than three fourths of the weight of the entire fouling community. *Crisia* sp., *Filicrisia franciscana* and *Bugula neritina* often grew abundantly with *Crisulipora*, but never were any of these dominant. Under the *Crisulipora* growth, and encrusting the surface of all submerged panels of 6 months age and older and all racks was *Lyrula hippocrepis*. *Holoporella brunnea* and massive fans of *Tubulipora pacifica* were also found in abundance. *Lyrula* was in all cases, however, the dominant encrusting bryozoan.

On the floating panels and those in the intertidal position, *Crisulipora* was usually completely replaced by *Bowerbankia gracilis* as the dominant erect bryozoan, and many panels and the racks in these positions had a thick furry growth of *Bowerbankia*. Under this blanket, however, was the ubiquitous *Lyrula hippocrepis* and, except on the intertidal and floating panels, *Holoporella*

*brunnea*. The encrusting bryozoan *Hippothoa hyalina*, the most conspicuous organism on practically all of the short term panels, was found on a few panels of the 3-month and 6-month series, but after this was not seen on the panels as a living organism. The dead remains of *Hippothoa* were often seen on 9- and 12-month panels under a smothering encrustation of *Lyrula hippocrepis*.

**Annelida:**

The dominant annelids were again, as before, the serpulid worms *Spirorbis spirillum* and *Serpula* sp. They were found on all panels except those in the intertidal series, but on the older panels were often smothered by *Lyrula* growth. On some of the 12-month panels, *Serpula* sp. attained a length of 8 cm and up to 0.5 cm in diameter.

**Arthropoda:**

*Balanus crenatus* was fairly common on only the intertidal panels at 3 months, but at 6 months this barnacle was very abundant on all except the deep wooden and asbestos panels. From then on, as the bryozoan growth increased, the barnacles declined. Under the layer of *Lyrula hippocrepis* could be seen the dead shells of many *B. crenatus*. *Balanus tintinnabulum* was never abundant, but on many of the panels except the deep ones from 1 to 5 large *B. tintinnabulum* could be found. The largest of these from the 12-month panels were 3 cm in diameter. A small number of *B. glandula* was found on the 12-month panels of the intertidal series, and a few were also observed on the stainless steel rack of the intertidal series and on the wooden floating rack.

**Mollusca:**

The dominant mollusk on the long term panels was, as on the short term ones, the nudibranch *Hermisenda crassicornis*. The dominant attached mollusk was *Hiatella arctica*. This nestling clam was found embedded in the fouling growth of panels at all depths, but was most abundant and attained the largest size on the floating panels. On some of these, and in crevices in the floating rack, after 12 months this mollusk reached a length of 3 cm and had siphons up to 5 cm long.

*Mytilus edulis* is a common wharf piling dweller yet is was found only in small numbers on the test panels and racks during this study. Never were more than 5 mussels found on any one panel, but they were sometimes of large size. Several mussels attached to the floating rack were 5 cm long when the rack was removed after 12 months.

Table 3

List of Species, and of Panels where Organisms Settled in Long Term Series  
October 1, 1966 to October 1, 1967

	3 months						6 months						9 months						12 months					
	L	I	F	S	D	A	L	I	F	S	D	A	L	I	F	S	D	A	L	I	F	S	D	A
<b>Algae:</b>																								
<i>Ulva</i> sp.	ND		ND																			2		
<i>Giffordia sandriana</i> (ZANARDINI) HAMEL, 1939	ND		ND				1																	
<i>Polysiphonia pacifica</i> HOLLENBERG, 1942	ND		ND																			2		
<i>Pterosiphonia dendroidea</i> (MONTAGNE) FALKENBERG, 1901	ND		ND										1									1		
<i>Brachioglossum woodii</i> (AGARDH) KYLIN, 1924	ND		ND																			1		
<b>Protozoa:</b>																								
<i>Cornuspira lajollaensis</i> UCHIO, 1960	ND		ND			2		2		2		2		2	3					2	3	3		2
<i>Rosalina columbiensis</i> (CUSHMAN, 1925)	ND		ND																	2	2			
<i>Zoothamnium</i> sp.	ND		ND																	2		2	2	
<i>Folliculina</i> sp.	ND		ND	3	3	3			3				3							3			3	2
<i>Ephelota gemmipara</i> (HARTWIG, 1876)	ND	3	ND														3							
<b>Porifera:</b>																								
<i>Leuconia heathi</i> (URBAN, 1905)	ND		ND	1	1					2	1	3	1			2	3	3	1				2	3
<i>Leucosolenia eleanor</i> URBAN, 1905	ND		ND	1	1	1	1	2		1	2		1	1	2	1		1	1	1	2			
<i>Rhabdodermella nuttingi</i> URBAN, 1902	ND		ND												1			1	1	1	1		1	
<b>Coelenterata:</b>																								
<i>Obelia</i> spp.	ND	3	ND					2					2	2	2		3		2				1	
<i>Syncoryne mirabilis</i> (AGASSIZ, 1862)	ND		ND												1					1				
<i>Hydractinia</i> sp.	ND		ND																	1				
<i>Corynactis californica</i> CARLGREN, 1936	ND		ND														1						1	
<b>Platyhelminthes:</b>																								
<i>Stylochoplana gracilis</i> HEATH & MCGREGOR, 1912	ND		ND			1	1			1						1							1	
<i>Notoplana acticola</i> (BOONE, 1929)	ND		ND				1	1	1	1	1	1										1	1	
<i>Thysanozoon californicum</i> HYMAN, 1953	ND		ND																1					
<i>Stylocheilus tripartitus</i> HYMAN, 1953	ND		ND																	2	2			
<b>Nemertea:</b>																								
<i>Micrura verrilli</i> COE, 1901	ND		ND																1				1	1
<i>Emplectonema gracile</i> (JOHNSTON, 1837)	ND		ND												1					1	1			
<i>Tetrastemma nigrifrons</i> COE, 1904	ND		ND						1	1	1								1					1
<b>Ectoprocta (Bryozoa):</b>																								
<i>Bowerbankia gracilis</i> O'DONOGHUE, 1926	ND		ND					3	3				3	3	3		3		2	3	2	2		2
<i>Filicrisia franciscana</i> (ROBERTSON, 1910)	ND		ND				1	1					1		1	1	1	1	1		1	1	1	
<i>Crisia</i> sp.	ND		ND												1	1	1				1		1	
<i>Crisulipora occidentalis</i> ROBERTSON, 1910	ND		ND	2	2		2	3	3	3	3	3	3		3	3	3	3	3		3	3	3	
<i>Tubulipora pacifica</i> ROBERTSON, 1910	ND		ND	2	3	3	3	2		2			3			2	3		2		2	2	2	
<i>Bugula neritina</i> (LINNAEUS, 1758)	ND		ND	1	1				1		1	1	1		1	1		1			2	1	1	
<i>Bugula californica</i> ROBERTSON, 1905	ND		ND	1	1	1	1											1	1		1		1	
<i>Hippothoa hyalina</i> (LINNAEUS, 1767)	ND		ND		2	3	2																	
<i>Lyrula hippocrepis</i> (HINCKS, 1882)	ND		ND	3	2	2	3	3	3	3	2	3	3	2	3	3	3	3	3	3	3	3	3	3
<i>Scrupocellaria californica</i> TRASK, 1857	ND		ND				2								1		1		2		2	2		
<i>Scruparia ambigua</i> (D'ORBIGNY, 1841)	ND		ND		1		1		1			1							1		1			
<i>Holoporella brunnea</i> (HINCKS, 1884)	ND		ND	3	2	2	3	3	3	3	3	3	2		2		2		3		2	2	2	
<b>Annelida:</b>																								
<i>Nereis vexillosa</i> GRUBE, 1851	ND		ND																		1			
<i>Nereis</i> sp.	ND		ND																				1	1
<i>Platynereis agassizi</i> (EHLERS, 1868)	ND		ND												2									
<i>Halosydna brevisetosa</i> KINBERG, 1855	ND		ND						1												3	3		

Table 3 [Continued]

	3 months						6 months						9 months						12 months					
	L	I	F	S	D	A	L	I	F	S	D	A	L	I	F	S	D	A	L	I	F	S	D	A
Annelida (continued)																								
<i>Pseudopotamilla ocellata</i> MOORE, 1905	ND		ND																		1			1
<i>Sabella</i> sp.	ND		ND									1	1											
<i>Spirorbis spirillum</i> (LINNAEUS, 1758)	ND		ND	3	2	3	2		1	2	2	2	2	2		2	2	2	2	2		2	2	2
<i>Serpula</i> sp.	ND		ND	2	2	2				2	2	2				2		2	2	2	2		2	2
<i>Polydora brachycephala</i> HARTMAN, 1936	ND		ND				1	1		3	3	3		1	1		2		2			1		1
Arthropoda:																								
<i>Balanus crenatus</i> BRUGUIÈRE, 1789	ND	3	ND	2		1	3	3	3	3	1		1	3	2	2				1	3	3	1	
<i>Balanus glandula</i> DARWIN, 1854	ND		ND																	1				
<i>Balanus tintinnabulum</i> (LINNAEUS, 1758)	ND		ND					1	1	1			1	1		1				1	1	1	1	
<i>Chthamalus</i> sp.	ND		ND					1							1									
<i>Limnoria quadripunctata</i> HOLTHUIS, 1949	ND	1	ND	2	1		3	3	3	3	2		3	3	3	3	3		3	3	3	3	3	
<i>Corophium insidiosum</i> CRAWFORD, 1937	ND		ND												2									
<i>Caprella</i> sp.	ND		ND											3			2					2	2	
<i>Cancer antennarius</i> STIMPSON, 1856	ND		ND																	1		1		
<i>Pachygrapsus crassipes</i> RANDALL, 1839	ND		ND																	1				
<i>Pugettia producta</i> (RANDALL, 1839)	ND		ND																	1				
<i>Loxorhynchus crispatus</i> STIMPSON, 1875	ND		ND																	1		1		
Mollusca:																								
<i>Pododesmus cepio</i> (GRAY, 1850)	ND		ND														2				2	2		
<i>Mytilus edulis</i> LINNAEUS, 1758	ND		ND			1	1	1					1						1	2				
<i>Pecten</i> sp.	ND		ND									1										1		
<i>Hiatella arctica</i> (LINNAEUS, 1771)	ND		ND			2		3	2	2	2		2	3		2			2	2	3	2	2	2
<i>Bankia setacea</i> (TRYON, 1863)	ND		ND								1								1	1	1		1	
<i>Hermisenda crassicornis</i> (ESCHSCHOLTZ, 1831)	ND	1	ND	1	1	1	1	1	2	1	1	1	1	1					1	1	2	1	1	1
<i>Doto kya</i> MARCUS, 1961	ND	1	ND																					
<i>Dendronotus frondosus</i> (ASCANIUS, 1774)	ND		ND					1						1						1				
<i>Acanthodoris brunnea</i> MACFARLAND, 1905	ND		ND					1																
<i>Triopha grandis</i> MACFARLAND, 1905	ND		ND	1			1									1						1		
<i>Cratena albocrusta</i> MACFARLAND, 1966	ND		ND				1																	
<i>Polycera atra</i> MACFARLAND, 1905	ND		ND				1												1				1	
<i>Aegires albopunctatus</i> MACFARLAND, 1905	ND		ND																1		1			
<i>Dirona picta</i> MACFARLAND, 1905	ND		ND																				1	
<i>Acmaea</i> sp.	ND		ND				1													1				
<i>Ischnochiton</i> sp.	ND		ND																			1		
Echinodermata																								
<i>Strongylocentrotus purpuratus</i> (STIMPSON, 1857)	ND		ND										1	1		2			1	1	2		1	
<i>Strongylocentrotus</i> sp.	ND		ND				1		1		1													
<i>Ophiotrix spiculata</i> LeCONTE, 1851	ND		ND																		1			
<i>Pycnopodia helianthoides</i> (BRANDT, 1835)	ND		ND																1					
<i>Pisaster</i> sp.	ND		ND																1			1	1	
<i>Eupentacta quinqueccmita</i> (SELENKA, 1867)	ND		ND																		1			
Chordata (Tunicata):																								
<i>Aplidium solidum</i> (RITTER & FORSYTH, 1917)	ND		ND														1			3	2	2		
<i>Ascidia ceratodes</i> (HUNTSMAN, 1912)	ND		ND								1	1		1	1	1		1	1	1	1	1	1	
<i>Styela montereyensis</i> (DALL, 1872)	ND		ND																	1	1			
<i>Styela truncata</i> RITTER, 1901	ND		ND																	1				
Weight of dried organisms scraped from one side of 8 inch by 10 inch panel			0.94 g				6.45 g						41.00 g						19.35 g					43.45 g
													37.40 g						26.27 g					28.25 g
													51.20 g						70.85 g					23.30 g
													46.00 g						9.10 g					56.85 g
													7.50 g						76.30 g					89.15 g
													21.50 g											16.60 g

For explanation of symbols, see next page

## Explanation of symbols used in Table 3

<sup>1</sup> Symbols used at head of columns indicate:

- |                      |                       |
|----------------------|-----------------------|
| L=Lighted panels;    | S=Shallow panels;     |
| I=Intertidal panels; | D=Deep wooden panels; |
| F=Floating panels;   | A=Asbestos panels     |

<sup>2</sup> Symbols in columns indicate:

ND=No data

1=species present in numbers from 1 to 10 individuals or colonies per panel side

2=species present in numbers from 11 to 20 individuals or colonies per panel side

3=species present in numbers upward from 20 individuals or colonies per panel side

In addition to *Hermisenda crassicornis*, many species of nudibranchs were observed on the long term panels, but always in small numbers.

**Echinodermata:**

The only echinoderms to appear regularly on the test surfaces were small green sea urchins. In the older panels these became purple and could be identified as *Strongylocentrotus purpuratus*. They were especially abundant on the floating rack and panels.

**Chordata (Tunicata):**

No tunicates were observed on the short term panels nor on those in the water for 3 months. On older panels, however, 4 species of tunicates were encountered. *Ascidia ceretodes* was on many of the panels of 6 months age and older and at one time or another was found on panels at all depths. It was never a dominant organism, and reached a maximum size at 12 months of about 3 cm across.

*Aplidium* (formerly *Amaroucium*) *solidum* made an inconspicuous first appearance on a deep asbestos panel at 9 months. At 12 months this tunicate was found in large numbers attached to all the racks and to panels in the intertidal, floating and shallow positions. On the intertidal rack and the 12-month intertidal panel, *A. solidum* was clearly the dominant organism, forming large massive slabs up to 10 cm across.

*Styela truncata* and *S. montereyensis* were found in small numbers on several of the 12-month panels and racks. On the floating panel and rack *S. montereyensis* reached a maximum length of 8 cm.

**WOOD BORING ORGANISMS**

In addition to a study of the fouling organisms found in Monterey Harbor, one of the purposes of this investigation was to check on the occurrence of wood boring animals. The presence of these destructive organisms in a harbor is usually of considerably more economic im-

portance than that of foulers. Two species of borers were found, the shipworm *Bankia setacea* and the gribble *Limnoria quadripunctata*. Some of the gribbles were small and lacked the characteristic tubercles on the telson as found in *L. quadripunctata*, so it is possible a second species of *Limnoria* is also present in the harbor.

*Bankia setacea* was found on only two of the short term plywood panels from the shallow series that were in the water between February 15 and April 1, 1967. In both cases the borers were very small and had just begun to excavate the wood. The first large shipworms were found on one deep panel of the long term series at 6 months. There were only 3 borers in the wood, but they were up to 5 cm long. None were found in the 9-month panels, but at 12 months large *Bankia* up to 8 cm long were found in the superficial layers of the plywood in the lighted, intertidal, floating and deep positions. In each panel there were usually 3 to 5 shipworms. The heaviest concentration of *Bankia* encountered was not in the panels, but in a board of 1 inch by 6 inch redwood that had served as a protective bottom in the stainless steel lighted rack. When removed after 12 months in the water this piece of wood was heavily fouled with bryozoans and looked sound externally, but it was absolutely riddled by large *B. setacea* up to 10 cm long and 0.7 cm in diameter. It is doubtful if there was any room in the wood for more shipworms, and the redwood crumbled when handled. Yet, the redwood rack that supported the floating panels appeared to be free of *Bankia*.

*Limnoria quadripunctata* was found on practically all the wooden short term panels throughout the year. Usually only from 1 to 5 animals were found on any one panel and they were often either wandering over the surface or at work in very shallow burrows. The panels in the shallow rack were most commonly attacked and supported the largest numbers of individual gribbles. On the long term panels, *Limnoria* was not found in great numbers until after the wood had been in the water 6 months or longer, but on these older panels, especially the 12-month series, the outer lamellae of the plywood were often completely riddled with burrows containing

both adult and juvenile *Limnoria*. It was interesting to note, however, that the encrusting bryozoans gave protection to the wood from gribble attack. Wherever extensive, unbroken layers of *Lyrula hippocrepis* covered the wood surface, no *Limnoria* burrows were found. In addition to the panels, the redwood floating rack carried gribbles in the superficial wood layers.

### SUMMARY

1. A series of 162 plywood and asbestos board panels were exposed in the water under Monterey Municipal Wharf No. 2 at various positions and water depths from October 1, 1966 to October 1, 1967.

2. Short term panels (exposed for 1 month) made it possible to determine season of settling of fouling and boring organisms, while long term panels (exposed for from 3 to 12 months) made it possible to measure rate of growth and determine the dominant foulers.

3. On short term panels, a total of 70 species of animals and plants settled on the surface, while on the long term panels 81 species were recorded.

4. With few exceptions on both the short term and long term panels, encrusting and erect bryozoans were the dominant fouling organisms. These included *Hippothoa hyalina*, *Lyrula hippocrepis*, and *Crisulipora occidentalis*.

5. *Balanus crenatus* was the dominant barnacle and was found on panels at all positions throughout the year.

6. Calcareous serpulid worms, *Spirorbis spirillum* and *Serpula* sp., were the most common annelids found.

7. Water temperature and salinity records were kept throughout the year but no clear correlation between these physical factors and the rate of fouling was noted with the possible exception of the influence of a generally higher temperature in late June and early July, 1967, on the settling at depths of *Balanus crenatus*.

8. Plywood and asbestos board, when exposed at 14 feet depth, collect essentially the same organisms and at the same rate.

9. The wood borers *Bankia setacea* and *Limnoria quadripunctata* attacked the plywood, especially in the long term panels.

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# Studies on the Vitality of the Japanese Pearl Oyster *Pteria (Pinctada) martensii* (DUNKER) under Abnormal Conditions - I. Oxygen Uptake and Shell Movement in Sea Water of Low Oxygen Content

BY

TETUO MIYAUTI

The Laboratory of Takashima Pearl Farm, Inc.  
Sasebo, Nagasaki Prefecture, Japan

(5 Text figures)

IN RECENT YEARS, the productivity of the sea water of pearl culture farms has decreased and, from time to time, shown low oxygen content.

In order to obtain further knowledge of the tolerance of oysters for this extreme environmental condition, the effects of low oxygen content of sea water on the rate of oxygen uptake and shell movement of Japanese pearl oysters have been studied and the results are reported in the present paper.

## MATERIALS AND METHODS

Japanese pearl oysters, *Pteria (Pinctada) martensii* (DUNKER), were reared in a pearl farm in Sasebo Bay, Nagasaki Prefecture. The shell length of the oysters was 6.0 to 7.3 cm and the age was 3 years.

Prior to the experiment the oysters were kept in a laboratory tank with running sea water for 2 days. The shells were cleaned to avoid errors due to the respiration of small organisms attached to their surface.

The apparatus used in this investigation, shown in Figures 1 and 2, was a modification of the type used by HALL (1929) for determination of oxygen uptake of fishes at different oxygen contents. One oyster was placed in a metabolism jar containing ca. 1.5 liters of sea water. Temperature fluctuation was kept at a minimum ( $20^{\circ} \pm 1^{\circ} \text{C}$ ) by keeping the jar in a water tank (A), which was supplied by filtered running water. The rate of water flow from the supply tank into the metabolism jar was kept constant (15 liters per hour) in order to avoid

the effect of current velocity which was reported by MIYAUTI & IRIE (1965, 1966a). The oxygen content of the water in the jar was controlled by varying the number of *Mytilus edulis* LINNAEUS, 1758, in the supply tank and the volume of inflowing water from the storage tank into the supply tank. To avoid the effect of daily rhythm (MORI, 1948a), oxygen uptake was measured once for every one hour period from 10 a. m. to 3 p. m.

In order to observe shell movement, the right valve of the oyster was fastened with alpha cyanoacrylate to a stone sinker placed at the bottom of the metabolism jar. A glass fibre thread attached to the outer margin of the left valve was linked to the lever of a kymograph (Figure 2), placed over the tank (A), and the shell movement was recorded on a weekly kymograph.

Determination of dissolved oxygen was made by the Winkler method. Experiments were carried out during October and November of 1965.

## RESULTS

**Oxygen Uptake:** The rate of oxygen uptake (cc/g dry tissue/hour) was obtained from determinations of the dissolved oxygen in the sea water flowing in and out of the metabolism jar.

The results of tests made on 5 oysters are shown in Table 1 and Figure 3. The rate of oxygen uptake remained nearly constant when the oxygen content of the sea water was maintained above 1.5 cc per liter. Below 1.5 cc of oxygen per liter, the uptake dropped abruptly.

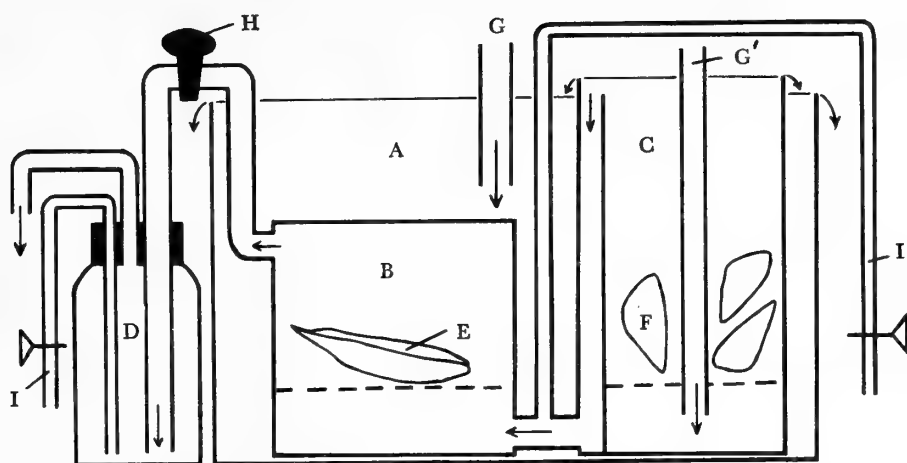


Figure 1

Apparatus used for the determination of oxygen uptake

A: water tank supplied with running sea water; B: metabolism jar;  
C: supply tank; D: water sample tank; E: pearl oyster;

F: *Mytilus edulis*; G, G': supply tube; H: stop cock;  
I, I': tube for taking samples of water

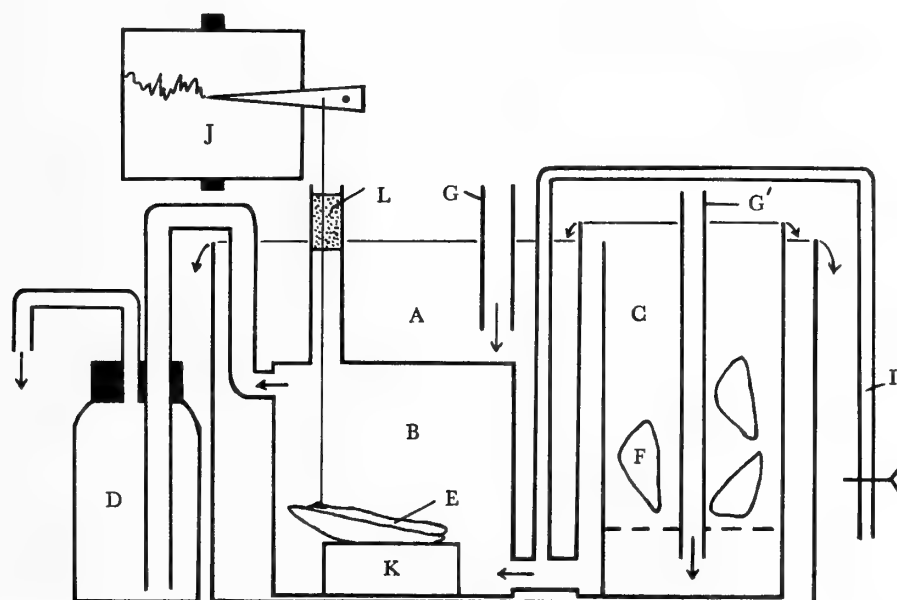


Figure 2

Apparatus used for the kymograph record of shell movement

A: water tank supplied with running sea water; B: metabolism jar;  
C: supply tank; D: water sample tank; E: pearl oyster;

F: *Mytilus edulis*; G, G': supply tube; H: stop cock;  
I, I': tube for taking samples of water

J: kymograph; K: stone sinker; L: liquid paraffin

Table 1

Relation between the rate of oxygen uptake of the pearl oysters and the oxygen content of the environment

Oxygen content (cc/L)	Oxygen uptake (cc/g dry tissue /hr)					Average
	A	B	C	D	E	
5.00 - 4.51	0.541	0.485	0.455	0.401	0.505	0.4774
4.50 - 4.01	0.537	0.499	0.445	0.379	0.488	0.4696
4.00 - 3.51	0.514	—	0.457	0.415	0.519	0.4762
3.50 - 3.01	0.526	0.495	0.450	0.375	—	0.4615
3.00 - 2.51	0.526	0.450	0.499	0.369	0.499	0.4586
2.50 - 2.01	0.491	0.451	—	0.419	—	0.4537
2.00 - 1.51	0.491	0.405	0.445	0.315	0.432	0.4176
1.50 - 1.01	0.298	0.098	0.279	0.086	0.217	0.1956
1.00 - 0.51	—	0.023	0.032	0.066	0.115	0.0590
0.50 - 0.15	—	0.011	0.014	0.024	0.009	0.0145

Date of experiment: October 22 to November 9, 1965

Cl: 18.01 to 18.45‰

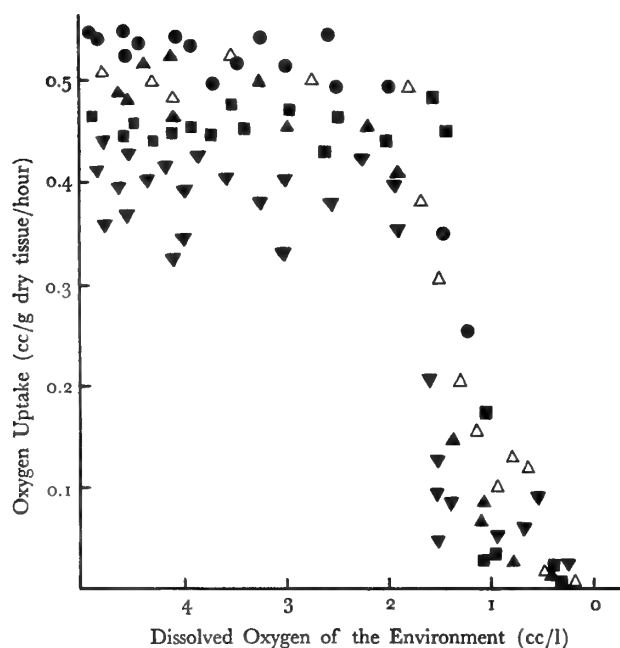


Figure 3

Effect of low oxygen content on the oxygen uptake rate of the pearl oysters

As shown in Table 1, the rate of oxygen uptake was 0.372 - 0.541 cc per g dry tissue weight<sup>1</sup> per hour when the amount of oxygen of the sea water was above 1.5 cc

per liter. MORI (1948 a) found it to be 0.029 - 0.068 cc per g wet tissue weight<sup>1</sup> per hour; MORI (1948 b), 0.02 - 0.05 cc per g wet weight per hour; SAWANO (1950), 0.074 to 0.1447 cc per g wet weight per hour; UEMOTO *et al.* (1964), 0.022 - 0.087 cc per g wet weight per hour; MIYAUTI & IRIE (1966 b), 0.3 - 0.6 cc per g dry weight per hour. These differences in value of the rate of oxygen uptake may be due to differences in experimental conditions, such as water temperature, age of oysters, experimental season, physiological condition of oysters and other parameters.

BERKELEY (1923) reports that the presence of the crystalline style in certain molluscs is related to anaerobic respiration. He observed that a mollusc maintained under anaerobic condition for 8 days lost the crystalline style entirely. On the other hand, NOZAWA (1929) found that the crystalline styles of *Ostrea circumpecta* disappear after anaerobic respiration, though not completely. In this experiment, the crystalline style diminished in size after 48 hours (but did not disappear entirely), under 0.5 cc oxygen content per liter of sea water.

**Shell Movement:** A representative kymograph record of shell movement under normal conditions during this experimental period is shown in Figure 4. Figure 5 shows shell movement at different levels of oxygen content. The results were obtained from 4 oysters.

Under normal conditions, the degree of valve opening showed periodic changes (daily rhythm), and the frequency of opening and closing was relatively low (Figure 4). If, however, the oxygen content was reduced to about 1.5 cc per liter, the frequency of opening and closing was much higher, and the degree of valve opening was greater. When the oxygen content was reduced to about 0.5 cc or less per liter, the daily rhythm of shell movement disappeared.

All oysters gradually regained their normal vitality when they were returned to a pearl farm after 3 to 7 days' experiments.

## DISCUSSION

The present experiments show that the rate of oxygen uptake and shell movement of the Japanese pearl oyster are independent of the oxygen content of the environment, when the latter is above 1.5 cc per liter.

It has been known that low oxygen content of the environment influences the physiological activity of the Japanese pearl oyster. According to SAWANO (1950) and

<sup>1</sup> 10 g wet tissue weight without shell is equivalent to about 1.2 to 1.3 g dry tissue weight without shell.

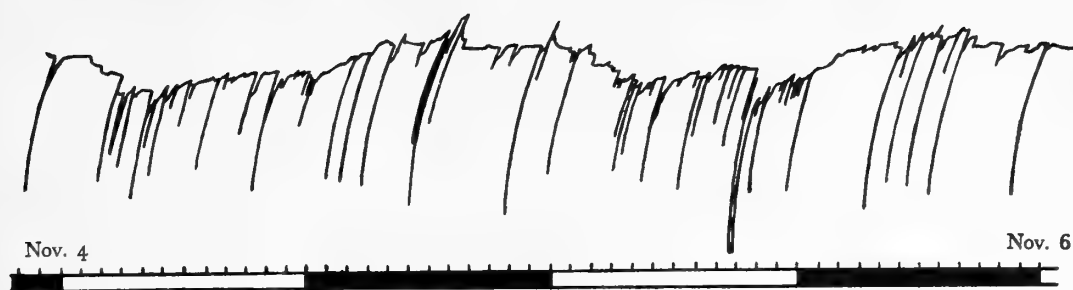


Figure 4

Kymograph record showing the shell movement of pearl oyster  
in normal sea water

White and black bands at the bottom show daytime (6:00-18:00) and night time (18:00-6:00). The writing pen is at the lowermost position when shell is closed.

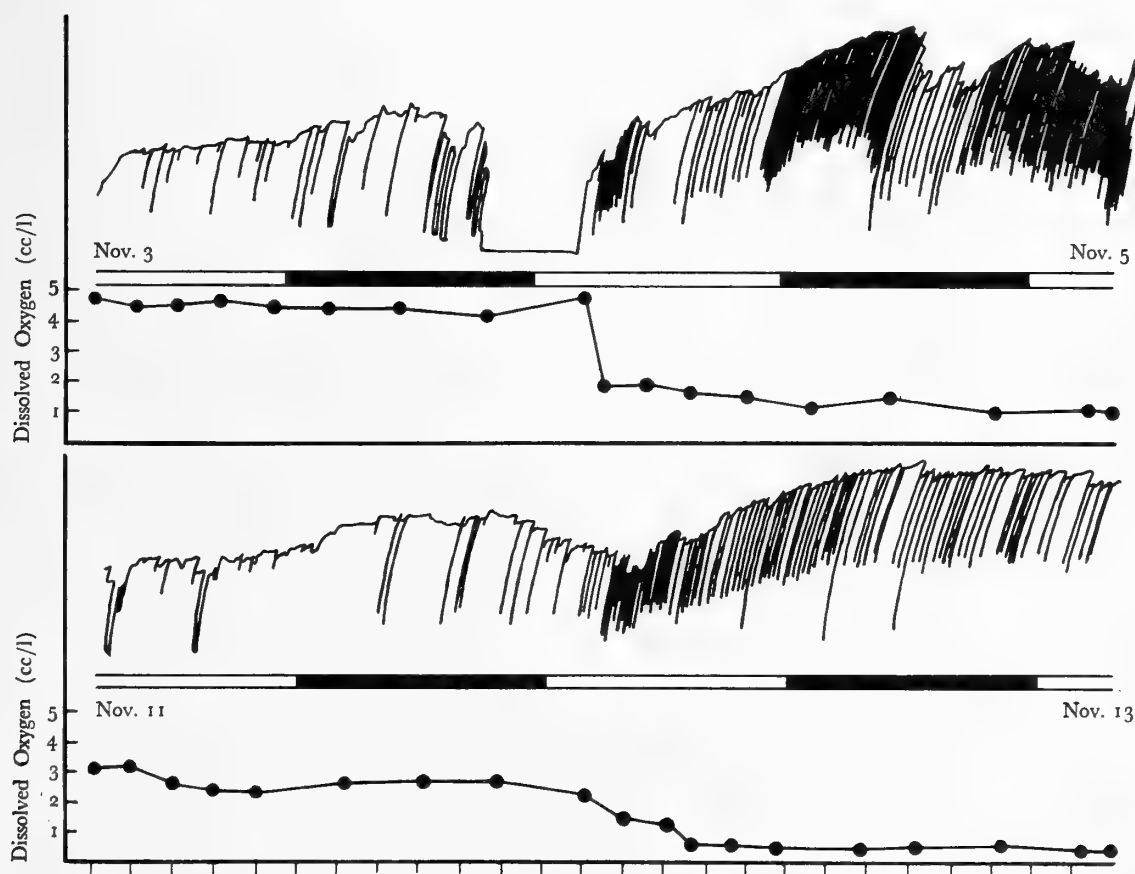


Figure 5 - continued next page

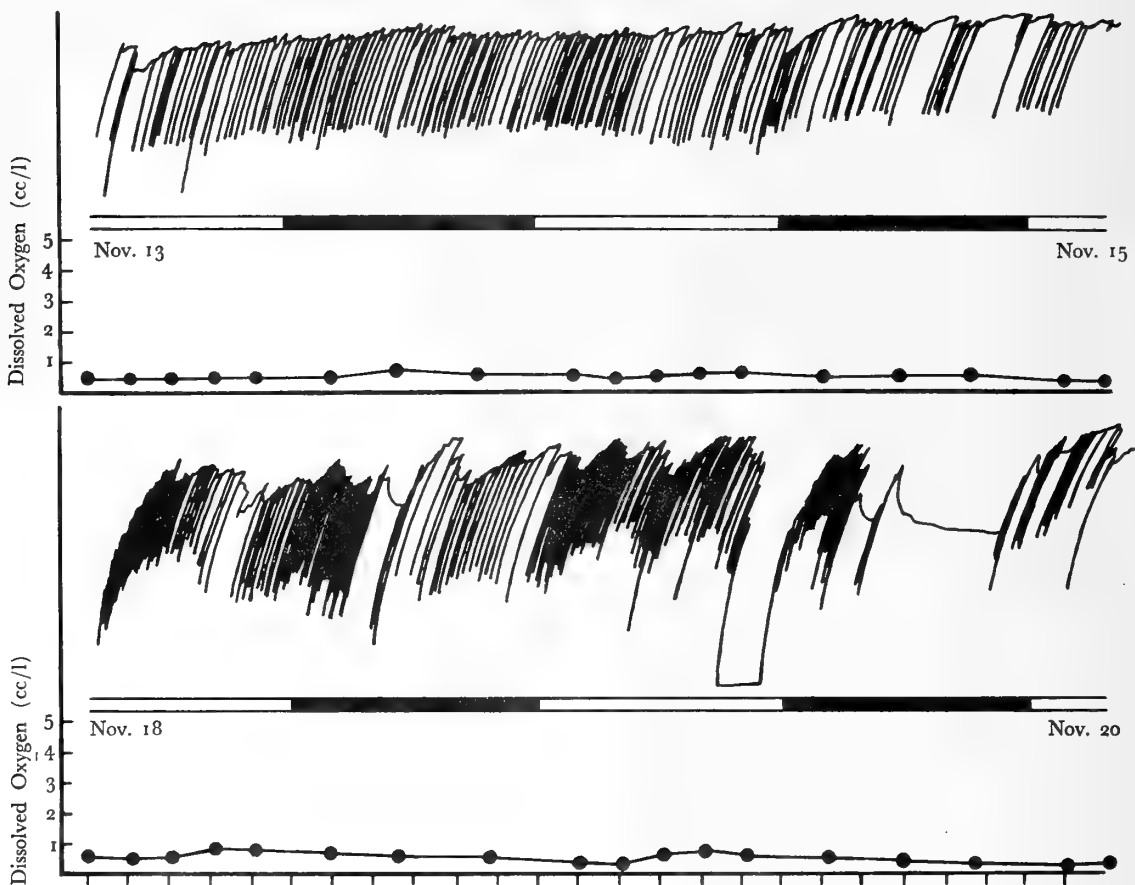


Figure 5

The effect of low oxygen content on the shell movement of the pearl oysters. The base line is marked in two-hour intervals.

UEMOTO *et al.* (1964), the rate of oxygen uptake of the pearl oyster was almost directly proportional to the oxygen content of the sea water. On the other hand, MORI (1948b) and MIYAUTI & IRIE (1966b) found that the rate stayed constant when the amount of oxygen of the sea water was above 0.5 cc per liter and 1.5 - 1.0 cc per liter, but it decreased considerably when the amount was lower than that level. The results of the former two studies differ from those of the present experiment; the latter are roughly similar to the present results. These differences in the rate of oxygen uptake may be due to differences in the experimental methods used. In the previous investigations, the water surface was covered with liquid paraffin. Consequently, the oxygen content was reduced continually as the oyster removed oxygen from

the water. Therefore, the results of such experiments do not accurately represent oxygen uptake at one particular oxygen content level. The method used in the present experiment, however, removes this difficulty, and fairly consistent results were obtained. In addition, the results of the present experiment are in agreement with those found for *Ostrea circumpecta* (NOZAWA, 1929), *O. edulis* (GALTSOFF & WHIPPLE, 1930), *Ostrea gigas* (ISHIDA, 1935), *Pecten grandis*, *P. irradians* (VAN DAM, 1954), *Mytilus edulis* (BRUCE, 1926; ROTTHAUWE, 1958), and *Anodonta cygnea* (HERS, 1943).

Low oxygen content also affects shell movement. MIYAUTI & IRIE (1966b) reported that when the oxygen content was reduced to 1.5 - 1.0 cc per liter or less, the frequency of shell movement was much higher and the

degree of opening of the valves was greater; when oxygen was reduced to 0.5 cc or less per liter, the degree of opening of the valves was slightly smaller; and when it was reduced to 0.2 cc or less per liter, the valves eventually gape open after closure for several ten-minute periods. The minor difference in shell movement between the above results and the present results may be ascribed to the use of a different method. In the previous investigation, the water surface was covered with liquid paraffin, so that the oysters may be affected by accumulated metabolites in addition to the low oxygen content.

The results of the present experiments do not necessarily indicate the response of the oyster as a whole animal. However, oxygen uptake and shell movement are important physiological factors controlling the vitality of the oyster; therefore these results will offer some fundamental data for the living conditions of oysters and will give an indication of the tolerance to low oxygen tension.

The most reasonable conclusion is that the pearl oysters are affected by low oxygen content only when the latter is 1.5 cc per liter, or less.

### SUMMARY

1. The effects of oxygen content on oxygen uptake and shell movement of the Japanese pearl oyster were studied.
2. The rate of oxygen uptake of this animal remained relatively constant until the oxygen content of the medium was decreased to 1.5 cc per liter.
3. The shell movement was generally normal until the oxygen content of the medium was decreased to 1.5 cc per liter.
4. Below 1.5 cc per liter, the rate of oxygen uptake dropped to a low level, and the shell movement was abnormal.

### ACKNOWLEDGMENTS

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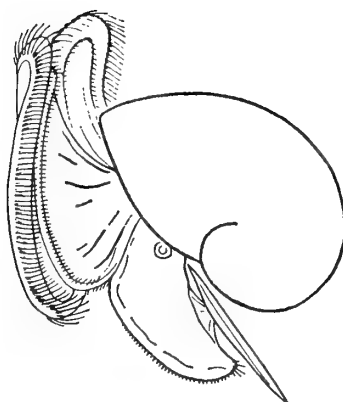
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# The Date of Publication of KIENER's *Mitra* Monograph in the "Spécies général et iconographie des coquilles vivantes"

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

THE INTERPRETATION OF THE DATES of issue of KIENER's "livraisons" of molluscan monographs has caused some difficulty to malacologists in view of the irregular appearance of the undated fascicles. SHERBORN & WOODWARD (1901), realizing the need for a stabilized interpretation of publication dates, collated KIENER's monographs as to the date of issue of text and plates. As in many instances the plates appeared prior to the text, KIENER's new species names are available from the date of issue of the plates which contain specific names on plate legends. SHERBORN & WOODWARD's collatory work (op. cit.) was based on external evidence as to the date of appearance of the fascicles; the authors realized that many gaps remain to be filled.

According to SHERBORN & WOODWARD (op. cit.) the plates to *Mitra* and *Voluta* were supposed to have been issued in fascicle 34, which they date from 22 April 1839; the complete set of plates and text of the monographs on *Mitra* and *Voluta* were said to have appeared in fascicles 34 - 47 during 1839. The text to *Mitra* and the plates to *Voluta* most probably were issued during 1839; however, there is evidence that the *Mitra* plates appeared already in 1838.

Evidence as to an earlier publication date of the *Mitra* plates may be found in EDUARD ANTON's "Verzeichniß der Conchylien" (1839), a work which is generally considered to antedate KIENER's *Mitra* monograph. A perusal of this publication shows, however, that ANTON's "Verzeichniß" postdates KIENER's *Mitra* monograph. The title page of the "Verzeichniß" bears the date 1839, ANTON's "Vorrede" (page iii) is dated 3 August 1838, and the last page, 110, bears the imprint "Im Druck beendigt den 9. Oktober 1838," meaning that by that date printing was completed. ANTON (page x) lists the titles of works used in his study, and acknowledged receipt of KIENER's 32 fascicles dated 1834 - 38 as follows: *Thracia*, *Pyramidella*, *Tornatella*, *Scalaria*, *Delphinula*, *Solarium*, *Rotella*, *Mitra*, *Struthiolaria*, *Purpura*, *Eburna*, *Terebra*, *Buccinum*, *Harpa*, *Dolium*, *Cassidaria*, *Cassis* and *Marginella*. In the text ANTON freely quotes

KIENER's species and figures of *Mitra*, the highest figure number cited from KIENER being 105. It is evident that prior to the completion of printing of the "Verzeichniß," i. e. 9 October 1838, ANTON received the complete set of *Mitra* plates (32 plates out of a total of 34 being cited), which must have appeared in or prior to fascicle 32. It appears, therefore, that the records of the "Bibliographie de la France" as cited by SHERBORN & WOODWARD (op. cit.) were correct after all when acknowledging receipt of KIENER's "livraisons 26 à 36" by December 1838. SHERBORN & WOODWARD suspected that this should have read 20 - 30.

It is evident that KIENER's *Mitra* monograph, apart from the text, should date from 1838, and that it antedates ANTON's "Verzeichniß." Since there is no evidence in ANTON's publication that the *Mitra* text appeared already in 1838, SHERBORN & WOODWARD's date of 1839 should be tentatively retained for the text alone. The species *M. cancellarioides* ANTON, which replaces *M. nodosa* SWAINSON, 1823 (non BORSON, 1820), has priority over *M. tuberculata* KIENER, which first appeared on plate 27, figure 87 as *M. fraga* (non QUOY & GAIMARD, 1833; nec KIENER, pl. 9, fig. 26). KIENER changed his homonymous *M. fraga* to *M. tuberculata* in the text to *Mitra* under the heading "Table des Espèces des Mitres" on page 119, which dates from 1839.

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## Itinerary of the Voyage of H. M. S. *Blossom*, 1825 to 1828

BY

JOSEPH ROSEWATER

Division of Mollusks, United States National Museum Smithsonian Institution, Washington, D. C. 20560

HIS MAJESTY'S SHIP *Blossom* under the command of Captain F.W. Beechey sailed to the Pacific and Arctic Oceans in the year 1825 and remained in that area until 1828 to provide support for an expedition mounted by the British for the purpose of discovering a northwest passage. The ship was scheduled to meet the expedition north of Bering Strait some time during the months of July, August or September of the years 1826 or 1827, and she was ordered to explore, chart and to collect natural history specimens during the balance of the time. Upon her return to England the natural history specimens were distributed to various naturalists for study. The mollusks were entrusted to J. E. Gray and his report on them appeared after numerous delays (GRAY, 1839; see also general introduction by F.W. BEECHEY, pp. vii, viii). In his introduction to the section on Mollusca, Gray remarked that a portion of the *Blossom* collections, mostly that collected by Captain Belcher and presented by him to the Zoological Society, was described by BRODERIP & SOWERBY (1829). Gray mentioned that he was including in his report additional material collected by others from some of the same areas that had been visited by the *Blossom*, but since he seldom named a collector or a precise locality, there is little basis for considering material to be from a source other than that voyage.

Unfortunately, naturalists of that day in many cases refrained from citing an exact locality for a species they were describing. Probably this was not entirely due to carelessness on their part, but often was the fault of collectors who neglected to label specimens properly. Today, this would be as inexcusable error, but at that time it probably seemed just not that important.

While working with the report on the *Blossom* Mollusca, in an attempt to identify certain Indo-Pacific marine mollusks, I found the quality of the locality data to vary considerably. Over 100 new species of mollusks are described in the report and locality information ranges in

precision from none at all to "Pacific" to relatively excellent data such as "Icy Cape." It will be noted that the section completed by G. B. SOWERBY (pp. 143 - 155) often contains considerably better locality information than that which precedes it written by GRAY (pp. 103 to 142). During a brief visit to the British Museum (N. H.) in 1963 I examined some of the types of species described by Gray in his report and found that the museum labels lacked additional locality data.

In many groups of mollusks it is of considerable importance to ascertain with fair precision the locality from which a particular species was described because similar-appearing but distinct species often live in widely separated regions. For this reason type localities are often designated in order to localize a taxon and to remove it from geographical limbo. To provide some basis for type locality designations in a similar case, CHAMBERLAIN (1960) prepared an itinerary of the voyage of the *Venus*. I have prepared the following itinerary of the voyage of the *Blossom*, and I hope it will obviate the necessity for future workers to search the cruise narrative to discover appropriate type localities.

BEECHEY (1831) prepared an elaborate narrative of the voyage of the *Blossom* containing rather complete and fascinating descriptions of the places and peoples visited. Events are related chronologically, but precise dates and places are buried in the text. In order to extract these for an itinerary it was necessary to read the narrative in some detail, a not unpleasant task. Where locality names differ appreciably from those recognized today, I have used either the modern name or indicated it in parentheses. The dates of visitation associated with each locality are not always certain and in some cases had to be left blank. It is often difficult to be sure from the cruise narrative that the ship actually stopped at a locality or whether it merely observed the position of an island or port while sailing past.

Localities	Arrival and/or Departure Dates		
Departed from Spithead, England	May 19, 1825	Nihau, Hawaii	June 1-2
Santa Cruz de Tenerife, Canary Ids.	June 2-5	Petropavlovsk, Bay of Awatska	June 28 to
Rio de Janeiro, Brazil	July 11-13	Kamchatka, U. S. S. R.	July 5
Rounded Cape Horn	September 16	Off Bering Island,	
Isla Mocha, Chile	October 6	Commander Islands, U. S. S. R.	July 10
Talcahuano and Concepción, Chile	October 8-20	Off St. Lawrence Island, Alaska	July 16
Valparaíso	October 27-29	Off King Island, Alaska	July 19
Off Sala-y-Gómez	November 15	Diomed Islands,	
Easter Island	Nov. 17-18?	Bering Strait, U. S. S. R.	July 20
Ducie Island	November 29	Schismareff Inlet, Cape Prince	
Henderson Island	December 3	of Wales, Alaska	July 21
Pitcairn Island	December 5 - 21	Kotzebue Sound, Alaska	July 22-23
Oeno Island	December 23	Chamisso Island, Mouth of	
Gambier Islands	Dec. 28, 1825	Eschscholtz Bay, Alaska	July 25-30
	Jan. 13, 1826	Cape Thompson, Alaska	August 2
Lord Hood's Island		Point Franklin, Alaska	August 15
(Marutea, Tuamotus)	January 14	Between Icy Cape and Cape	
Clermont Tonnerre		Beaufort, Alaska	August 20
(Reao, Tuamotus)	January 18	Point Hope, Alaska	August 26
Serle Island		Return to Chamisso Island	August 28
(Pukarua, Tuamotus)	January 21	Explorations of Kotzebue Sound	
Whitsunday Island		and vicinity while waiting for	
(Pinaki, Tuamotus)	January 22	Captain Franklin and shore party	
Queen Charlotte's Island		(September 10; return of Barge	
(Nukutavake, Tuamotus)	January 23	from north to 71° 23' 31" N and	
Lagoon Island		156° 21' 30" W)	August 29 to
(Vahitahi, Tuamotus)	January 24		October 14
Egmont Island		King Island, Alaska	October 16
(Vairaatea, Tuamotus)	January 25?	St. Paul, Pribilof Islands, Alaska	October 21
Barrow Island		Unimak, Aleutian Islands, Alaska	October 22
(Vanavana, Tuamotus)		San Francisco, California	November 7 to
Carysfort Island			December 28
(Tureia, Tuamotus)		Monterey, California	January 1-5, 1827
Osnaburgh or Matilda		Honolulu, Hawaii	January 26 to
(Mururoa, Tuamotus)	February		March 3
Byam Martin Island		Left Hawaii	March 4
(Ahunui, Tuamotus)		South of Wake Island	March 15
Gloucester Island		Assumption (Asuncion, Marianas)	March 25
(Paraoa, Tuamotus)		Bashee Islands (Batanes Islands)	April 7
Bow Island		Macao	April 10-30
(Hao, Tuamotus)	Feb. 15-20	Naha, Okinawa, Ryukyu Ids.	May 18-25
Tahiti, Society Islands	March 18 to	Bonin Islands	June 8
	April 26	Petropavlovsk, Bay of Awatska	
Oahu, Hawaii	May 19-31	Kamchatka, U. S. S. R.	July 3-20
		Bering Island,	
		Commander Islands, U. S. S. R.	July 22
		St. Lawrence Island, Alaska	August 1

King Island, Alaska	August 2
Chamisso Island, Kotzebue Sound, Alaska (Lieut. Belcher takes Barge north to explore Icy Cape)	August 5
Cape Krusenstern, Alaska	August 25
Chamisso Island, Kotzebue Sound, Alaska	August 26
Cape York, Alaska	August 31
Exploring north to vicinity of Icy Cape and southward to Port Clarence and return to Kotzebue Sound waiting for Capt. Franklin and shore party	October 6
Passing Bering Strait and in vicinity of St. Lawrence Island, Alaska	October 6-7
St. Paul, Pribilof Islands	October 12
Unimak Island, Aleutian Islands	October 14
Monterey, California	October 29 to November 17
San Francisco, California	November 18 to December 3
Off Cape St. Lucas, Baja California, Mexico	December 13
Off Tres Marias Islands, Mexico	December 14
San Blas, Mexico	December 16
Mazatlán, Mexico	February 3 to Feb. 7, 1828
Exploration of coast between Mazatlán and San Blas	February 7
Left San Blas, Mexico	March 8

Acapulco, Mexico	March 13-18
Crossed Equator	March 29
Valparaíso, Chile	April 29 - May 20
Coquimbo, Chile	May 23 - June 3
Cape Horn	June 30
Rio de Janeiro, Brazil	July 21
Spithead, England	October (prior to 12 <sup>th</sup> , 1828)

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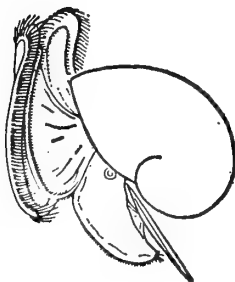
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# The Ovulidae, Pediculariidae and Triviidae of Fiji

(Mollusca : Gastropoda)

BY

WALTER OLIVER CERNOHORSKY

Vatukoula, Fiji Islands

(Plates 50 to 52; 5 Text figures; 1 Map)

## INTRODUCTION

THIS IS THE EIGHTH PART in the series of faunal monographs dealing with the marine mollusca of the Fiji Islands.

Unlike the Cypraeidae, species of Ovulidae, Pediculariidae and Triviidae are moderately rare in Fiji; the minute size and often inaccessible habitat are responsible for their rare occurrence in local collections.

All the species recorded from the Fiji Islands have a Pacific or Indo-Pacific distribution, and the majority of species live within the area of the East African coast and the Tuamotu Archipelago.

In this, as in the previous monographs, only species collected by resident collectors and the author are listed as verified records. For notes on the geography of the Fiji Islands and other pertinent data see CERNOHORSKY, 1964.

## TAXONOMY

The higher categories of Cypraeacea have been discussed in a recent publication by SCHILDER (1966). Despite the non-binding recommendation by the International Commission on Zoological Nomenclature that the ending "-oidea" be employed for Superfamilies, most malacologists have accepted the ending "-acea" since the publication of THIELE's 'Handbuch der systematischen Weichtierkunde' (1929). The taxon Cypraeacea has been introduced by SCHILDER (1927) and was accepted by THIELE (*op. cit.*) and most subsequent authors. The superfamilial term Cypraeoidea has been used by IREDALE (1935) and SCHILDER (1939, 1941). Cypraeoidea has, however, been recently re-introduced into literature by IREDALE & McMICHAEL (1962), and the suffix '-acea' has been retained in this publication for some subclasses of molluscs. In view of the non-binding recommendation regarding term endings for superfamilies in zoology, a

standardization of such suffixes by malacologists would be welcome.

The family Lamellariidae has been removed from the Cypraeacea by previous authors and placed in the superfamily Lamellariacea; the families Cypraeidae, Ovulidae, Pediculariidae, and Triviidae have been retained in the Cypraeacea. In a broad classification of all mollusca, the erection of a new superfamily Triviacea for the reception of Triviidae and Pediculariidae, would not appear to contribute to a clearer definition of relationships between these allied families. A continuous upgrading of higher categories of Cypraeacea by specialists may finally result in monofamilial superfamilies if further divisions will prove imperative. Since the ranking of higher taxonomic categories is largely subjective, a retention of Triviidae and Pediculariidae in the Cypraeacea may appear orthodox to the specialist, but would not tend to obscure existing phylogenetic relationships between the families; it would also be more consistent with our present classification of higher categories of other gastropod groups.

Species of Ovulidae have been assigned to various generic groups since the start of organized nomenclature: *Bulla* LINNAEUS, 1758; "*Amphiperas*" GRONOVIVS, 1781 (non binomial); *Ovula* BRUGUIÈRE, 1789; *Volva* and *Cyphoma* RÖDING, 1798; and *Radius* SCHUMACHER, 1817. MONTFORT (1810), who had a decided preference for generic names of masculine gender changed *Ovula* to *Ovulus* and also established *Calpurnus* and *Ultimus*, while SOWERBY (1828) introduced *Ovulum*, which he considered properly latinized. The genera *Ovula* and *Ovulum* remained in use for the remainder of the 19<sup>th</sup> century together with *Simnia* RISSO, 1826, *Radius* SCHUMACHER and *Neosimnia* FISCHER, 1884. In the early part of the 20<sup>th</sup> century "*Amphiperas*" was re-introduced and several new genus-group names were proposed by THIELE (1925, 1929), SCHILDER (1927) and IREDALE (1930, 1931, 1935).

Living species of Pediculariidae had a less eventful taxonomic history, due mainly to the small number of species and the somewhat belated appearance of the first Recent species, *Pedicularia sicula* SWAINSON, 1840, in molluscan literature. The authors H. and A. ADAMS (1854) erected the family Pediculariidae and the genera *Pediculariella* THIELE, 1925 and *Pediculariona* (IREDALE, 1935, *nud.*) SCHILDER, 1939 were subsequently established. Most authors considered Pediculariidae worthy of familial rank, but SCHILDER (*op. cit.*) combined all species in the subfamily Pediculariinae within the family Ovulidae; in 1966, however, he distinguished Ovulidae from Pediculariidae and transferred the latter family to Triviacea.

As far as the Triviidae are concerned, authors were unable to reach agreement as to generic placement of the species. Species of Triviinae and Eratoinae were assigned to *Cypraea* LINNAEUS, 1758, *Bulla* LINNAEUS, 1758, *Voluta* LINNAEUS, 1758, *Marginella* LAMARCK, 1799, *Columbella* LAMARCK, 1799, and other lesser known genera. The introduction of the new genera *Erato* RISSO, 1826, *Lachryma* SOWERBY [1832], (introduced inadvertently), *Trivia* BRODERIP, 1836, *Triviella*, *Trivirostra*, *Niveria* and *Pusula* JOUSSEAUME, 1884, did not appreciably change the taxonomic concept of this group; species of Triviinae continued to be assigned to the Cypraeidae, and Eratoinae to Marginellidae. SCHILDER (1927) thoroughly revised the group according to phylogeny, and IREDALE (1930, 1931, 1935) contributed to the subdivision of the family by establishing several new genus-group names whose validity is seriously questioned by practising malacologists.

### IREDALE'S GENUS-GROUP NAMES

Several adverse comments have been passed by recent malacologists and zoologists on the validity of genus- and species-group names proposed by IREDALE (ZILCH, 1960; SOLEM, 1964). Whatever the taxonomic shortcomings of IREDALE's generic diagnoses, their brevity and casualness appear to be the product of taxonomic procedures prevalent among malacologists at the time, in contrast to

present-day systematics. It is unfortunate that authors continue to use genus-group names proposed by IREDALE, which in accordance with the rules of the Code of the ICZN (1964) are *nomina nuda*. Although a common-sense interpretation of the Code of the ICZN appears advisable at times, the rules governing the availability of zoological names are unequivocal: a name can be either valid or invalid, but not tentatively valid.

The usage of Iredalean genus-group names in this monograph made it advisable to test each scientific name established by Iredale between 1930 and 1935 as to its taxonomic availability. It became apparent that Iredale's names fall into three categories: 1) names which are technically and scientifically valid; 2) names which are technically *nomina nuda*; and 3) names which are technically valid but scientifically *nomina dubia*.

The majority of Iredale's names proposed prior to 1931 satisfy the requirements of art. 12 in conjunction with art. 16(v) or 16(vi) of the Code of the ICZN; their definition may not be scientifically adequate, but they are certainly available. Names established after 1930 are either valid, invalid or *nomina dubia*; the first must be accepted, the second rejected; it is the *nomina dubia* which will pose a taxonomic problem.

A list of genus-group and specific names proposed by IREDALE (1931, 1935), which qualify as *nomina nuda* (art. 13, ICZN) is appended. In all cases these genus-group names have been diagnosed by SCHILDER (1939) and validated by SCHILDER as author:

#### *Ellatrivia* (IREDALE, 1931, *nud.*) SCHILDER, 1939

1931. *Ellatrivia* IREDALE, Rec. Aust. Mus. 18: 221 (nom. nud.)  
 1935. *Ellatrivia* IREDALE, Aust. Zool. 8: 100 (nom. nud.)  
 1935. *Ellatrivia* SCHILDER, Proc. Malacol. Soc. London, 21: 330 (nom. nud. — no type fixation, art. 13(b) of ICZN)  
 1939. *Ellatrivia* SCHILDER, Arch. Molluskenk. 71: 173, fig. 26 (type spec. by OD *Triviella merces* IREDALE, 1924)

#### *Fossatrivia* (IREDALE, 1931, *nud.*) SCHILDER, 1939

1931. *Fossatrivia* IREDALE, Rec. Aust. Mus., 18: 222 (nom. nud.)  
 1935. *Fossatrivia* IREDALE, Aust. Zool., 8: 100 (nom. nud.)  
 1939. *Fossatrivia* SCHILDER, Arch. Molluskenk., 71: 173 (type spec. by OD *Trivia caelatura* HEDLEY, 1918)

### Explanation of Plate 50

- Figure 1: *Ovula ovum* (LINNAEUS). Fiji. (x 0.5)  
 Figure 2: *Ovula costellata* (LAMARCK). Fiji. (x 1.0)  
 Figures 3 and 3a: *Calpurnus verrucosus* (LINNAEUS). Fiji. (x 2.0)  
 Figure 4: *Calpurnus lacteus* (LAMARCK). Fiji. (x 2.5)  
 Figure 5: *Primovula punctata* (DUCLOS). Fiji. (x 3.0)

Figure 10: *Phenacovolva birostris* (LINNAEUS). Fiji. (x 2.5)

- Figure 6: *Prionovolva fruticum* (REEVE). Fiji. (x 2.0)  
 Figure 7: *Prosimnia coarctata* (ADAMS & REEVE). Fiji. (x 3.5)  
 Figure 8: *Primovula striatula* (SOWERBY). Fiji. (x 5.0)  
 Figure 9: *Volva volva* (LINNAEUS). Fiji. (x 0.6)  
 Figure 9a: *Volva volva* (LINNAEUS). Fiji, juvenile specimen (x 1.0)



Figure 1

Figure 2

Figure 3

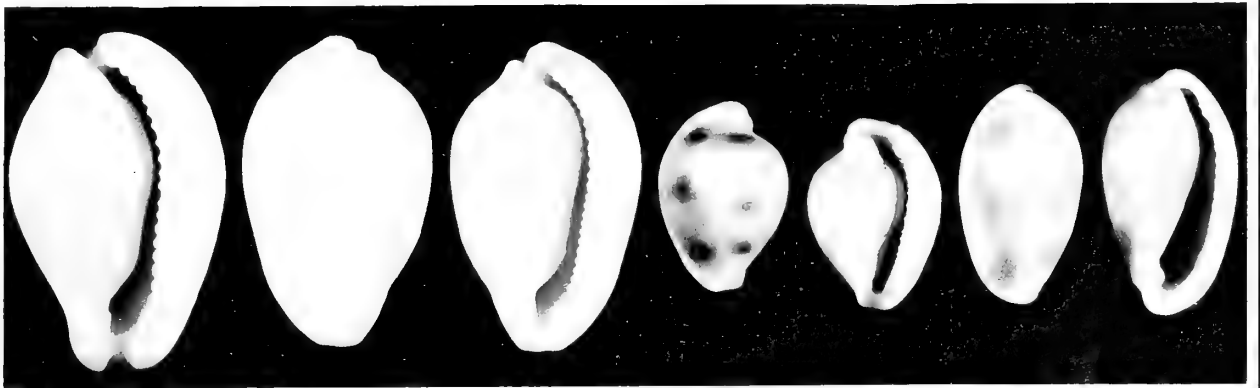


Figure 3 a

Figure 4

Figure 5

Figure 6



Figure 7

Figure 8

Figure 9

Figure 9 a

Figure 10



*Volva volva cumulata* (IREDALE, 1931, *nud.*) IREDALE, 1935

1931. *Volva volva cumulata* IREDALE, Rec. Aust. Mus., 18: 222 (nom. nud.)  
 1932. *Volva cumulata* SCHILDER, Proc. Malacol. Soc. London, 20: 56 (nom. nud.)  
 1935. *Volva volva cumulata* IREDALE, Aust. Zool. 8: 104

*Pellasiimnia* (IREDALE, 1931, *nud.*) SCHILDER, 1939

1931. *Pellasiimnia* IREDALE, Rec. Aust. Mus., 18: 222 (nom. nud.)  
 1932. *Pellasiimnia* SCHILDER, Proc. Malacol. Soc. London, 20: 54 (in synonymy of *Neosimnia* FISCHER, 1884 – no type fixation, art. 13(b) of ICZN)  
 1935. *Pellasiimnia* IREDALE, Aust. Zool. 8: 104 (nom. nud.)  
 1939. *Pellasiimnia* SCHILDER, Arch. Molluskenk., 71: 195 (type spec. by OD *Ovulum angasi* REEVE, 1865)

*Margovula* (IREDALE, 1935, *nud.*) SCHILDER, 1939

1935. *Margovula* IREDALE, Aust. Zool. 8: 103 (nom. nud.)  
 1939. *Margovula* SCHILDER, Arch. Molluskenk. 71: 200 (published in synonymy of *Diminovula* IREDALE, 1930 – type spec. by OD *M. pyriformis* (SOWERBY, 1828))  
 1941. *Margovula* SCHILDER, Arch. Molluskenk. 73: 68

*Margovula* appears to have been validated by SCHILDER (1939) through publication in synonymy (art. 11(d) of ICZN) and subsequent adoption by SCHILDER (1941) as a senior synonym of *Diminovula* IREDALE, 1930.

*Pediculariona* IREDALE, 1935 (p. 101) was diagnosed as follows: "The elevated sculptured spire later buried in the shell separates this [*Pediculariona*] distinctly, and there are representatives of this in Queensland." This inadequate diagnosis could be interpreted as a statement purporting to give characters differentiating the taxon, but by the same token it is this particular diagnostic character which places it in the synonymy of *Pedicularia* SWAINSON, 1840.

## METHODS

The nomenclature of diagnostic characters of Ovulidae follows SCHILDER (1932, p. 57, fig. 20). The number of dorsal ribs quoted for species of Triviidae consists of the total of centrally-placed ribs on both sides of the dorsal groove or dorsal centre; the loop-like ribs confined within the outlets of the extremities have been excluded from the count. Only mature specimens have been utilized for morphometric measurements.

The following abbreviations are used in this paper:

- L = Length of shell expressed in millimeters (mm)  
 W = Width of shell expressed in % of length  
 H = Height of shell expressed in % of length  
 LT = Number of labial teeth

## ACKNOWLEDGMENT

I would like to express my appreciation to Mr. D. Heppell, Royal Scottish Museum, Edinburgh; Drs. H. Rehder and J. Rosewater, Smithsonian Institution, U. S. National Museum, Washington; Dr. F. A. Schilder, Halle, and Mr. N. Tebble, British Museum (Natural History), London, for their assistance with reference material and other information. The permission to publish photographs of the types of *Ovulum margarita* SOWERBY, received from the Trustees of the British Museum (Natural History), London, is gratefully acknowledged.

I wish to thank the following collectors for the loan of study material: Mrs. M. Ashton, Proserpine; Mr. R. F. Browne, Nausori; Mr. J. Candries, Suva; Mrs. F. Fitzmaurice, Kurrimine Beach; Mr. & Mrs. F. Freitag, Suva; Mr. & Mrs. A. Jameson, Lautoka; Mr. A. Jennings, Auckland; and Mrs. M. Wood, Nadi.

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(\* denotes synonym or homonym)

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## MESOGASTROPODA

### CYPRAEACEA

#### OVULIDAE FLEMING, 1828 (*nom. corr.*)

#### OVULADAE)

1854. AMPHIPERASIDAE H. & A. ADAMS, Gen. Rec. Moll., 1: 269

1929. AMPHIPERATIDAE WINKWORTH, Proc. Malacol. Soc. London, 18: 298

The shells of Ovulidae are pyriform or fusiform in shape, uni-coloured, spotted or banded, and the extremities are either short or produced; shells are smooth or transversely striate and some species have a dorsal carina. The labial side is margined, columellar side rounded, labial lip with or without denticles, columella generally edentulous.

The animals are similar to the Cypraeidae, i. e. they possess a foot, mantle, tentacles, eyes, and a siphon; the papillae, however, are generally shorter. The anatomy of the Ovulidae has been described by THIELE (1929) and SCHILDER (1932, 1939, 1944).

The radula is taenioglossate with 7 teeth per row; Recent species of Eocypraeinae have an additional edentulous connecting plate. Rhachidians are variable, but generally have a large central cusp and often side-denticles; laterals are large, with a beak-like main cusp and generally side-denticles on the cutting edge. Marginals are fairly uniform throughout the family and the inner marginals are smaller than the outer ones; flabellae are numerous, slender, extended, recurved and bifid or sometimes trifid at the distal end. SCHILDER (1932) considered the anatomy and radula features of Ovulidae to be rather similar among the genera and subgenera, and his subdivision has therefore been restricted to differences in shell morphology. Although the marginals are basically similar

throughout the family, the rhachidians and sometimes the laterals exhibit appreciable differences between species of different genera; on the other hand, however, the radular features of some species of Ovulinae may resemble those of Simniinae.

The majority of Recent ovulids lives in the Indo-Pacific region, and only a few species live in other major faunal regions.

Some Ovulidae share the same habitat with cypraeids, while others are associated with octocorals and sea-fans. The food-requirements of tropical ovulids are not known; however, food is possibly extracted from the same host-coral on which they live.

#### Ovulinae FLEMING, 1828

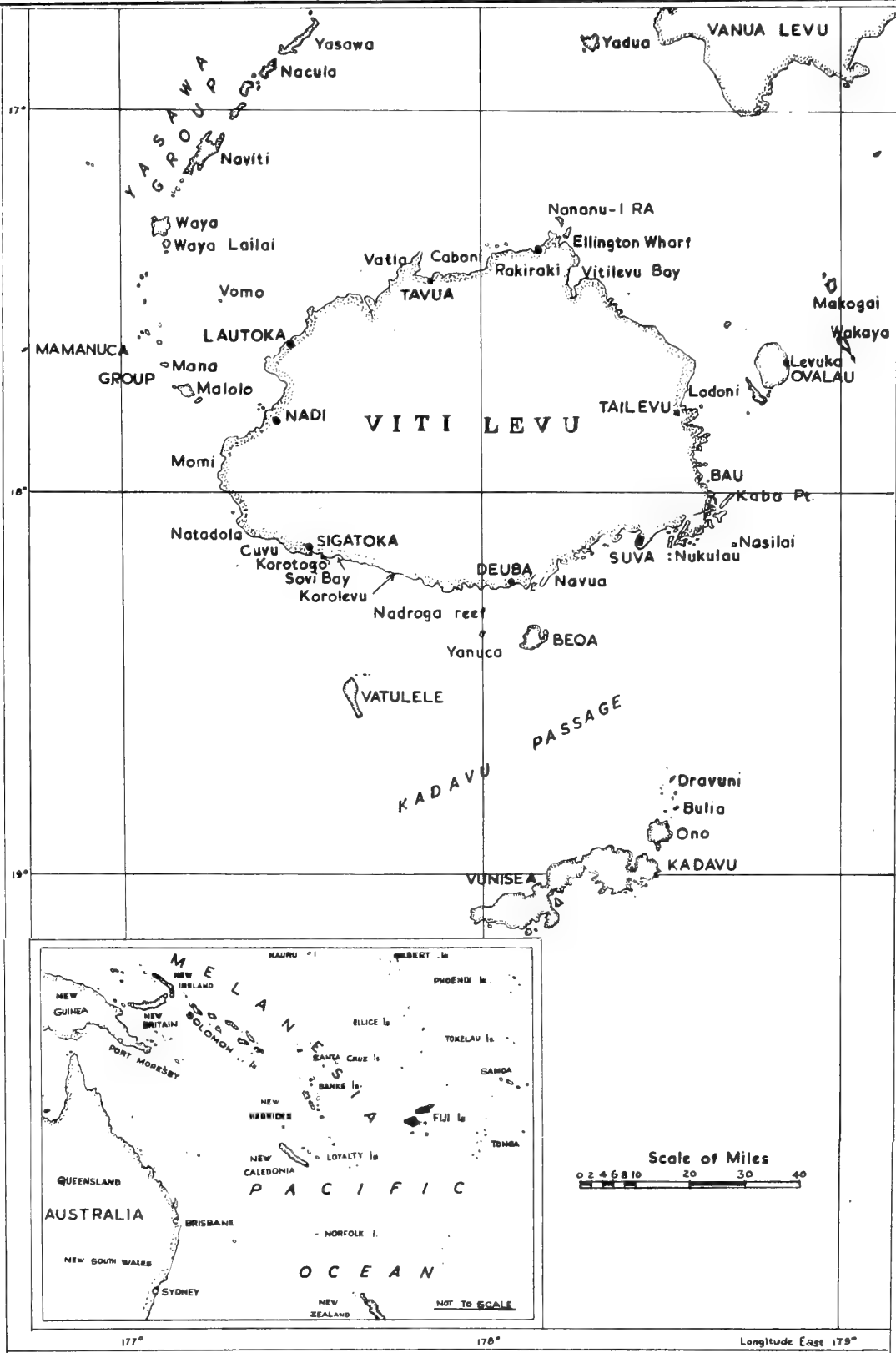
1929. Amphiperasinae THIELE, Handb. syst. Weichtierk., p. 270

1932. Amphiperatinae SCHILDER, Proc. Malacol. Soc. London, 20: 46

The subfamily contains a group of species with pyriform, inflated shells with short extremities, a plain, spotted or banded dorsum, which is either smooth, transversely striate or carinate. Columellar teeth are absent, labial teeth developed and the anterior terminal ridge on the columella is prominent; the fossula is smooth and broad. The rhachidians and lateral teeth of the radula are variable, marginals with numerous slender flabellae.

Species of Ovulinae are distributed in all major Oceans, but species of the genus *Pseudosimnia* SCHILDER, 1927, are restricted to the Mediterranean and the Eastern Atlantic.

Species of Ovulinae inhabit crevices of coral rocks, or occasionally live in folds or at the base of soft coral or on gorgonians.



*Ovula* BRUGUIÈRE, 1789

*Ovula* BRUGUIÈRE, 1789, Hist. nat. vers, Index, p. 15. Type species by SD (LAMARCK, 1801) *Ovula oviformis* LAMARCK, 1801 = *Bulla ovum* LINNAEUS, 1758.

1781. "*Amphiperas*" GRONOVIVS, Ind. Zooph. Gron., p. 293 (non binom.)  
 1798. *Ovula* LAMARCK, Tabl. Encycl. Méth., plts. 357-358 (no type selected)  
 1810. *Ovulus* MONTFORT, Conch. Syst., 2: 634 (nom. nov. pro *Ovula* BRUGUIÈRE, 1789)  
 1828. *Ovulum* SOWERBY, Zool. Journ. 4: 145 (nom. nov. pro *Ovula* BRUGUIÈRE, 1789)  
 1935. *Parlicium* IREDALE, Aust. Zool., 8: 101 (Type species by OD *Ovula costellata* LAMARCK, 1811)

The genus contains the two largest species of the family Ovulidae; their shells are smooth or obsoletely carinate, the interior is dark in colour, the columella is edentulous and labial teeth are irregular. Only two Recent Indo-Pacific species are known, and fossil species have so far not been recorded.

**Discussion:** The genus *Parlicium* IREDALE has been established for *Ovula costellata* LAMARCK on the basis of a difference in animal features and the formation of the posterior canal. Differences in animal features are specific characters and the diagnostic difference in the formation of the posterior canal appears to be of insufficient taxonomic importance to warrant the erection of a new monotypic genus.

*Ovula ovum* (LINNAEUS, 1758)

(Plate 50, Figure 1)

1758. *Bulla ovum* LINNAEUS, Syst. Nat., ed. 10, p. 725, no. 327  
 1798. *Volva cygnea* RÖDING, Mus. Bolt., p. 21, no. 255  
 1811. *Ovula oviformis* LAMARCK, Ann. Mus. Hist. Nat., 16: 110  
 1817. *Ovula alba* SCHUMACHER, Ess. nouv. syst., p. 258  
 1828. *Ovulum ovum* var. *pygmaea* SOWERBY, Zool. Journ. 4: 149  
 1905. *Amphiperas ovum* (LINNAEUS), BERGH, Siboga Exp., 50: plt. 5, fig. 21 (animal)

**Shell:** Large and ovate, extremities produced, porcellaneous white, interior orange-brown; dorsum either moderately smooth or with 1 - 4 fine transverse carinate lines. Labial lip convex, teeth irregular and often bifid, numbering from 35 to 45; columella edentulous, second funiculum strong and projecting, fossula absent.

L: 65 - 110 mm; W: 58 - 64%

**Type Locality:** Oceano Asiatico ("Amboina," IREDALE, 1935).

**Habitat:** On soft coral, from 1 - 4 fathoms. Common.

**Distribution:** Throughout the Fiji Islands. - From Madagascar through the tropical Indo-Pacific to the Tuamotu Archipelago.

*Ovula costellata* LAMARCK, 1811

(Plate 50, Figure 2)

1811. *Ovula costellata* LAMARCK, Ann. Mus. Hist. Nat. 16: 110  
 1817. *Ovula imperialis* DILLWYN, Descr. cat. rec. shells 1: 470  
 1822. *Ovula angulosa* LAMARCK, Anim. sans vert., 7: 367  
 1829. *Ovula columba* SCHUBERT & WAGNER, Conch. Cab., 12: 116; plt. 228, figs. 4043, 4044

**Shell:** Pyriform and inflated, white in colour, centre of dorsum occasionally pink, interior violet; dorsum with an obsolete dorsal carina, transverse carinate lines and striae at extremities. Labial lip convex, teeth irregular, numbering from 19 to 23; columella edentulous, occasionally with 3 - 4 obsolete columellar teeth, anterior terminal ridge obsolete, fossula absent.

L: 38 - 42 mm; W: 62 - 65%

**Type Locality:** L'Océan des Grandes Indes ("Friendly Isles," MARTYN, 1886) [= Tonga Islands].

**Habitat:** On soft coral, from 1 - 4 fathoms. - Rare.

**Distribution:** Southwest Viti Levu. - From East Africa through the tropical Indo-Pacific to Japan and the Tonga Islands.

*Calpurnus* MONTFORT, 1810

*Calpurnus* MONTFORT, 1810, Conch. Syst., 2: 638. Type species by OD *Bulla verrucosa* LINNAEUS, 1758.

1840. *Cypraella* SWAINSON, Treat. Malac., p. 325 (Type species by M *Bulla verrucosa* LINNAEUS, 1758)

Shells of the genus are moderately small, angulately pyriform, smooth or striate, and white in colour; the dorsal carina is prominent, obsolete or absent, extremities with or without a yellow-ringed wart-like knob. Columella is edentulous, labial lip prominently denticulate.

The radula (*vide* SCHEPMAN, 1909) has rhachidians which carry a massive central cusp which protrudes over the concave plate margin; one small accessory denticle is

## Explanation of Plate 51

- Figure 11: *Phenacovolva gracilis* (ADAMS & REEVE). Fiji. (x 2.5)  
 Figure 12: *Phenacovolva philippinarum* (SOWERBY). Fiji. (x 1.3)  
 Figure 13: Host coral of *Phenacovolva philippinarum*. Fiji. (x 1.0)  
 Figure 14: *Pseudocypraea adamsonii* (SOWERBY). Fiji. (x 5.0)

Figure 19: *Trivirostra hordacea* (KIENER). Fiji. (x 8.0)

- Figure 15: *Trivirostra oryza* (LAMARCK). Fiji. (x 4.0)  
 Figure 16: *Trivirostra* species (= ? *T. scabriuscula* GRAY). Fiji. (x 5)  
 Figure 17: *Trivirostra edgari* (SHAW). Fiji. (x 4.5)  
 Figure 18: *Trivirostra exigua* (GRAY). Fiji. (x 6.5)



Figure 11

Figure 12

Figure 13

Figure 14

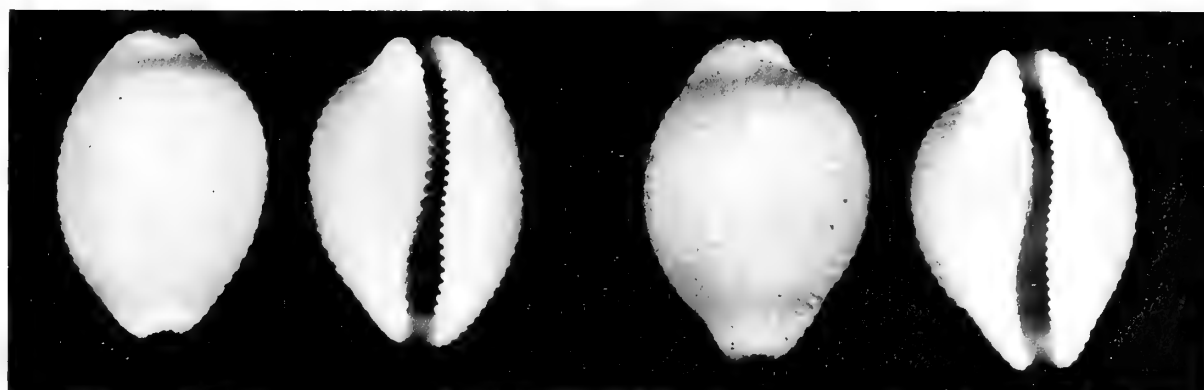


Figure 15

Figure 16

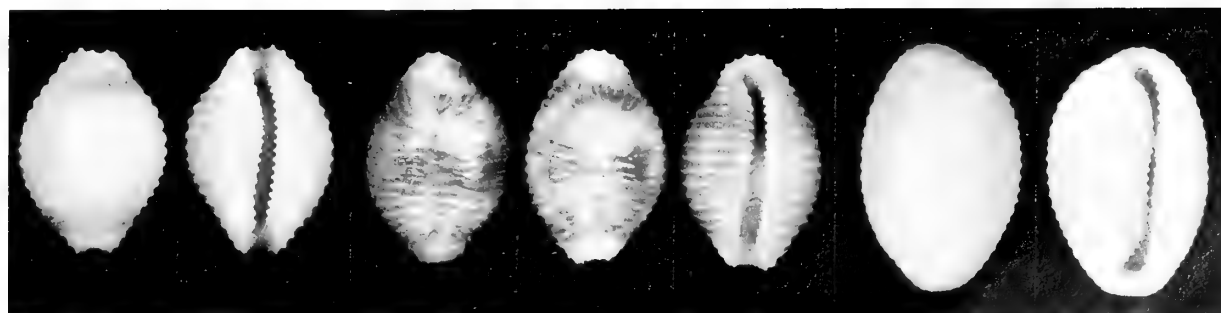


Figure 17

Figure 18

Figure 19



positioned at either side of the cusp; laterals are simple and curved, and a small denticle is positioned centrally on the main cusp; marginals are similar to those of other groups of Ovulidae.

Species of *Calpurnus* are associated with soft coral.

*Calpurnus (Calpurnus) verrucosus* (LINNAEUS, 1758)

(Plate 50, Figures 3, 3 a)

1758. *Bulla verrucosa* LINNAEUS, Syst. Nat., ed. 10, p. 726, no. 330

1798. *Volva perla* RÖDING, Mus. Bolten., p. 22, no. 260

1909. *Calpurnus verrucosus* (LINNAEUS) SCHEPMAN, Siboga Exp., 49b: 146; plt. 15, fig. 10 (radula)

1935. *Calpurnus verrucosus* (LINNAEUS) IREDALE, Aust. Zool., 8: 102; plt. 8, figs. 4, 4 a (animal)

**Shell:** Angulately ovate and humped, white in colour, extremities flushed with light rose-purple, ornamented with 2 prominent orange-ringed wart-like tubercles. Dorsum with a prominent central transverse carina and numerous fine striae; sides minutely granulose, granules extending partly towards dorsum. Aperture dilated anteriorly, labial lip flattened and with 17-23 prominent teeth which extend towards the margins; columella edentulous, columellar anterior ridge indistinct, fossula shallow and smooth.

**Animal:** Foot and siphon are white in colour, mantle is smooth, white to greyish-white, spotted with small pink spots over entire mantle surface.

L: 18 - 27 mm; W: 59 - 67%

**Type Locality:** In India Orientali ("Amboina," IREDALE, 1935).

**Habitat:** In folds and at the base of soft coral, in shallow and deeper water. — Moderately common.

**Distribution:** Throughout the Fiji Islands. — From Madagascar through the tropical Indo-Pacific to Japan and the Fiji Islands.

**Discussion:** In the majority of Fiji specimens examined, the anterior extremity is partly recurved towards the aperture.

(*Procalpurnus*) THIELE, 1929

*Procalpurnus* THIELE, 1929, Handb. syst. Weichtierk., p. 272. Type species by M *Ovula lactea* LAMARCK, 1811.

The subgenus, which is monotypic, contains a species which lacks the wart-like nodes at extremities and central dorsal carina. The rhachidians of the radula of the type species of *Procalpurnus* are also dissimilar to those of the type species of *Calpurnus*.

*Calpurnus (Procalpurnus) lacteus* (LAMARCK, 1811)

(Plate 50, Figure 4)

1811. *Ovula lactea* LAMARCK, Ann. Mus. Hist. Nat., 16: 111

1863. *Amphiperas semistriata* PEASE, Proc. Zool. Soc. London for 1862: 241 ("Pacific Islands")

1935. *Procalpurnus lacteus* (LAMARCK), IREDALE, Aust. Zool. 8: 103; pl. 8, figs. 3, 3 a (animal)

1965. *Amphiperas semistriata* PEASE, KAY, Bull. Brit. Mus. (Nat. Hist.) Zool. Suppl. 1: 74; plt. 12, figs. 5, 6 (lecto-type)

**Shell:** Elongate-ovate to broadly ovate, white in colour; the dorsal carina is obsolete in most specimens, but some specimens show 1 or 2 weak carinae. Dorsum with 20-50 transverse striae which are distributed along the entire length of the shell but may become obsolete centrally and confined to the extremities. Labial lip is flattened, teeth

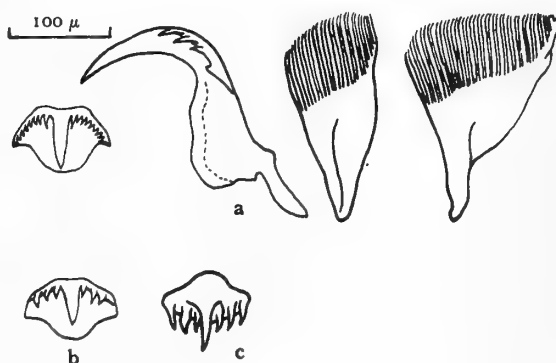


Figure 1

*Calpurnus (Procalpurnus) lacteus* (LAMARCK)

Fiji Islands

a - Half row of radular teeth

b - Rhachidian of radula (ventral view) c - (dorsal view)

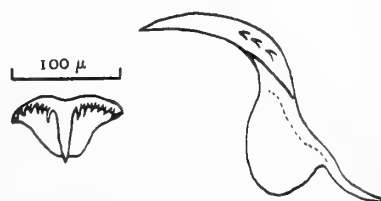


Figure 2

*Calpurnus (Procalpurnus) lacteus* (LAMARCK)

Pearl Reef, Queensland, Australia

Rhachidian and lateral teeth of radula

prominent, numbering from 20 to 31; columella edentulous, anterior columellar terminal ridge prominent and oblique, fossula smooth.

**Animal:** Foot blackish-grey, mantle smooth, jet-black and ornamented with small white spots; tentacles black, siphon black and finely ciliated at the distal end.

**Radula:** The odontophore is 4.6 mm long and 0.68 mm wide in an animal with a shell 17.4 mm in length; fully formed rows of teeth number 138 (plus 14 nascentes) and early rows of teeth are greatly worn. The rhachidian is small, 0.09 mm wide, with a long central cusp and 3 - 9 side-cusps; laterals are large, with a massive main cusp and 3 - 4 side denticles. Inner marginals have *ca.* 18 and outer marginals *ca.* 38 flabellae which are curved and bifid at the distal end.

A specimen from Queensland had a radula 3.9 mm long and 0.7 mm wide and a shell 17.8 mm in length; the rhachidians were 0.1 mm wide and the ribbon contained 132 rows (plus 9 nascentes) of teeth.

L: 12 - 19 mm; W: 54 - 63%

**Type Locality:** Timor.

**Habitat:** At the base of soft coral, from 0 - 4 fathoms.

Uncommon.

**Distribution:** Throughout the Fiji Islands. — From the Red Sea through the tropical Indo-Pacific to the Society and Hawaiian Islands.

#### *Prosimnia* SCHILDER, 1927

*Prosimnia* SCHILDER, 1927, Arch. Naturgesch. 91A: 77. Type species by OD *Ovula semperi* WEINKAUFF, 1881 = *Ovulum coarctatum* ADAMS & REEVE, 1848.

The shell of the type species is elongate-cylindrical, the dorsum is carinate and spirally striate, labial lip densely denticulate, columellar lip with short denticles on axis, fossula narrow and denticulate.

The radula of the type species has been described by SCHILDER (1944, p. 32) and was said to be somewhat similar to the radula of *Pseudosimnia carnea* (POIRET, 1789) as figured by THIELE (1929, fig. 287). The radula of *Primovula beckerii* (SOWERBY, 1900) differs appreciably from that of *Prosimnia coarctata* (*vide* BARNARD, 1963, p. 50, fig. 6c).

#### *Prosimnia coarctata* (ADAMS & REEVE, 1848)

(Plate 50, Figure 7)

1848. *Ovulum coarctatum* ADAMS & REEVE, Zool. Voy. Sam., p. 21; pl. 6, figs. 2a, 2b

1881. *Ovula semperi* WEINKAUFF, Conch. Cab., ed. 2, 5: 190; pl. 48, figs. 14, 15

1882. *Ovula semperi* WEINKAUFF, Jahrb. Deut. Malakol. Gesellschaft, p. 174 (nom. corr.)

1944. *Primovula coarctata* (ADAMS & REEVE), SCHILDER, Ark. Zool., 36A: 32 (descr. radula)

**Shell:** Small, slender and cylindrical, orange-brown or orange-fawn in colour, labial margin and labial lip bright yellowish-orange. Dorsum sculptured with a prominent elevated dorsal keel and occasionally 1 - 2 smaller keels; transverse striae vary in thickness and number from 55 to 70 and are intersected by longitudinal growth striae. Labial lip flattened and curved, teeth sharply sculptured but irregular and numbering from 43 to 53, partly extending over the shell-margin; columella denticulate almost along entire length to funiculum, teeth small, numbering from 45 to 50; anterior columellar terminal ridge is absent, first funiculum is crenulate, second funiculum prominent, fossula narrow and projecting, smooth and denticulate.

**Animal:** Foot light orange, mantle orange to red, siphon and tentacles reddish-orange, eyes black.

L: 11 - 13 mm; W: 31 - 36%

**Type Locality:** Straits of Sunda, near Java.

**Habitat:** On red gorgonian coral, from 2 - 3 fathoms. Moderately rare.

**Distribution:** South and West Viti Levu. — From Madagascar through the tropical Indo-Pacific to Japan and the Fiji Islands.

#### *Primovula* THIELE, 1925

*Primovula* THIELE, 1925, KÜCKENTHAL, Handb. Zool., 5: 88. Type species by OD *Amphiperas beckerii* SOWERBY, 1900.

1961. *Dentiovula* HABE, Col. illust. shells Japan, 2: 41; pl. 19, fig. 1 [Type species by M *D. dorsuosa* (HINDS, 1844)]

1961. *Dentiovula* HABE, Col. illus. shells Japan, 2: App. p. 14 [Type species by OD *D. dorsuosa* (HINDS, 1844)]

1963. *Dentiovula* HABE, SHIKAMA, Sel. shells world, 1: 45; pl. 32, fig. 15 (first reviser)

Shells are small, cylindrical-fusiform, occasionally with a light-coloured central band, a dorsal carina and striae; labial lip flattened, prominently or irregularly denticulate, columella edentulous, labial margin often serrate.

The radula (*vide* BARNARD, 1963) has horizontally egg-shaped rhachidians with a short and stout central cusp and 3 - 4 side denticles; laterals are moderately slender with a main cusp and 4 - 5 accessory denticles on cutting edge; marginals similar to those of other genera of Ovulidae.

**Discussion:** HABE (1961) established *Dentiovula* on page 41 and later on, on Appendix page 14 described *Denti-*

*volva* in Japanese. In accordance with art. 32 b of the Code of ICZN (1964), *Dentiovula* is the correct spelling as selected by SHIKAMA (1963), who appears to be the first reviser. The new genus name, however, seems superfluous.

*Primovula (Primovula) striatula* (SOWERBY, 1828)  
(Plate 50, Figure 8)

1828. *Ovulum striatulum* SOWERBY, Zool. Journ., 4: 155  
1830. *Ovulum striatulum* SOWERBY, Spec. Conch., *Ovulum*, 1: 7, fig. 38  
1848. *Ovulum dentatum* ADAMS & REEVE, Zool. Voy. Sam., p. 21; plt. 6, figs. 4 a, 4 b (non *Ovula dentata* FISCHER, 1807)  
1930. *Prosimnia renovata* IREDALE, Mem. Qld. Mus., 10: 85 (nom. nov. pro *Ovula dentata* ADAMS & REEVE, 1848)  
1932. *Prosimnia verconis* COTTON & GODFREY, South Aust. Nat. 13: 46; plt. 1, fig. 15  
1963. *Primovula striata* (sic) SOWERBY, SHIKAMA, Sel. shells world, 1: 45  
1963. *Neosimnia tinctura* GARRARD, Journ. Malacol. Soc. Aust. 7: 45; plt. 7, figs. 5, 6

**Shell:** Small, cylindrically-fusiform, dark pink in colour with one white central transverse band and pale pink margins and extremities; the dorsum is sculptured with 50 - 60 fine transverse striae and a dorsal carina which may be obsolete. Labial lip is flattened, labial teeth sometimes obsolete anteriorly but reaching margins posteriorly, numbering from 25 to 28; in some specimens the labial teeth are very large and reach as far as the outlets. Anterior columellar terminal ridge is obsolete, first funiculum with 3 - 5 denticles, second funiculum pronounced or indistinct, interior of columella finely striate, fossula excavate and smooth.

**L:** 7 - 9 mm; **W:** 35 - 39%

**Type Locality:** Ad littora Oceani Indici; East Indies [= Indonesia].

**Habitat:** Dredged from 15 - 18 fathoms on coral. Rare.

**Distribution:** West off Viti Levu. - From the Persian Gulf through the tropical Indo-Pacific to Japan and the Fiji Islands.

**Discussion:** Fiji specimens are more slender in comparison with specimens from other regions (W: 41 - 49%). The species is extremely variable in colour, some specimens being purplish-pink or purple; for further notes on the species see SCHILDER, 1964.

(*Diminovula*) IREDALE, 1930

*Diminovula* IREDALE, 1930, Mem. Qld. Mus., 10: 85. Type species by OD *D. verepunctata* IREDALE, 1930 = *Ovula punctata* DUCLOS, 1831

1935. *Margovula* IREDALE, Aust. Zool., 8: 103 (nom. nud.)

1939. *Margovula* SCHILDER, Arch. Molluskenk., 71: 200 (Type species by OD *M. pyriformis* (SOWERBY, 1828))

Species of the subgenus are characterized by their small pyriform shells and somewhat produced extremities; the dorsum is smooth or striate, unicoloured or spotted, labial teeth are developed, columellar teeth obsolete; first funiculum distinct, crenulate or smooth, fossula smooth and concave.

The radula of the type species was not available, but the radula of *Diminovula bimaculata* (A. ADAMS, 1855) from Queensland was examined; this species has essentially similar morphological features as the type species, and has been assigned by SCHILDER (1941) and other authors to *Diminovula*. The radular ribbon was 6.6 mm long and 0.9 mm wide in an animal with a shell 13.5 mm in length; the ribbon contained 111 rows of teeth (plus 12 nascentes) and early rows of teeth were greatly worn. The rhachidian is small, 0.17 mm wide, with a long central cusp and 2 - 3 cusps at either side; laterals large and unicuspid, inner marginals slender and with ca. 12 flabellae, outer marginals broad and with 21 - 23 flabellae.

The radula is basically similar to the radula of *Ovula angasi* REEVE, 1865, the type species of *Pellasiimnia* (vide SCHEPMAN, 1909), in the subfamily Simniinae; it also resembles the radula of *Primovula beckerii* (SOWERBY, 1900) in the subfamily Ovulidae. The laterals are unicuspid in *Diminovula bimaculata*, but denticulate on the cutting edge of the main cusp in *Pellasiimnia angasi* and *Primovula beckerii*; this feature, however, is a variable characteristic in other taenioglossate radulae, e.g. in Cymatiidae and Bursidae.

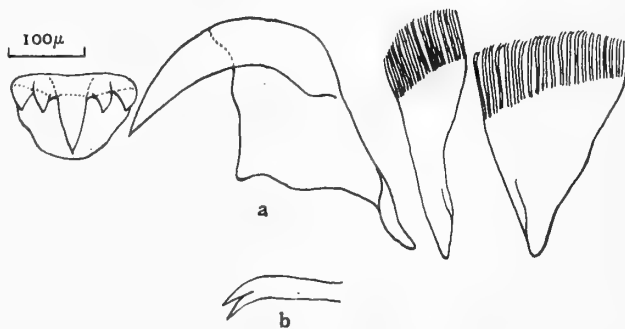


Figure 3

*Primovula (Diminovula) bimaculata* (A. ADAMS)

- a - Half row of radular teeth  
b - Distal end of flabella (enlarged)

*Primovula (Diminovula) punctata* (DUCLOS, 1831)

(Plate 50, Figure 5)

1831. *Ovula punctata* DUCLOS, Mag. de Zool., 1: 7; plt. 7, fig. 11930. *Diminovula verepunctata* IREDALE, Mem. Qld. Mus., 10: 851932. *Primovula (Diminovula) cristallina* (KIENER), SCHILDER, Proc. Malacol. Soc. London, 20: 51; plt. 3, figs. 2, 3, 4 (? non KIENER, 1843)

**Shell:** Small and pyriform, extremities slightly produced; white to creamy-white in colour, generally ornamented with 3 pairs of white spots on dorsum. Some specimens have additional orange transverse lines descending onto the margins from the anterior and posterior pair of spots, and an orange line follows the periphery of the labial margin; extremities are tinged with light yellow. The dorsum is sculptured with 25-60 fine transverse striae; labial lip is convex, labial teeth are irregular but prominent, numbering from 19 to 28. The anterior terminal ridge is well developed, columella edentulous, first funiculum projecting and rounded at end, sculptured with 4-7 irregular denticles; first posterior outlet is shallow, second funiculum and outlet are obsolete. Fossula is concave and smooth, interior of columella smooth or striate. L: 6-11 mm; W: 57-65%

**Type Locality:** I. Bourbon [= Réunion Island, Indian Ocean]

**Habitat:** Under coral rocks, in shallow and deeper water. Moderately rare.

**Distribution:** North and Southwest Viti Levu. - From East Africa through the tropical Indo-Pacific to Japan and the Fiji Islands.

**Discussion:** The *Primovula cristallina* of SCHILDER (1932) is conspecific with *P. punctata*. The holotype of *Ovula cristallina* KIENER, preserved in the Paris Museum, is a worn and calcified *Diminovula* species (*fide* SCHILDER, 1932); in view of the bad preservation of the holotype it is doubtful whether *Ovula cristallina* is a good species or conspecific with *Primovula punctata*.

*Prionovolva* IREDALE, 1930

*Prionovolva* IREDALE, 1930. Mem. Qld. Mus., 10: 85. Type species by OD *Ovulum breve* SOWERBY, 1828

1941. *Prionovola* (sic) SCHILDER, Arch. Molluskenk. 73: 117

1964. *Prionovola* (sic) CERNOHORSKY, The Veliger 6: 200

The genus contains ovate to pyriform shells which are either banded or unicoloured; the dorsum is smooth, but spirally striate at extremities, labial teeth are irregular but prominent, columella is edentulous. The genus differs

from *Primovula* in the prominently projecting smooth funiculum and columellar carina.

*Prionovolva fruticum* (REEVE, 1865)

(Plate 50, Figure 6)

1865. *Ovulum fruticum* REEVE, Conch. Icon., *Ovulum*, 15, plt. 4, sp. 16 a, 16 b

**Shell:** Elongate-ovate, white to pinkish-white in colour, ornamented with 3-4 dark pink transverse bands; margins and base are white. The dorsum lacks a dorsal carina, and is sculptured with 8-30 transverse striae which are generally confined to the extremities; labial lip is flattened, teeth sharply sculptured, numbering from 19 to 25; some of the labial teeth (*ca.* 2-7) extend towards the margin which becomes serrate. Aperture dilated anteriorly, columella edentulous and with a sharp columellar carina, anterior columellar terminal ridge prominent; first funiculum prominent, smooth and projecting, second funiculum absent, fossula short and concave.

L: 10-15 mm; W: 52-59%

**Type Locality:** Malacca.

**Habitat:** Dredged from 10-18 fathoms on coral.

Moderately rare.

**Distribution:** West Viti Levu. - From East Africa through the tropical Indo-Pacific to Japan and the Fiji Islands.

**Discussion:** The dorsal spiral striae are generally confined to the extremities, but may extend across the dorsum, becoming somewhat obsolete centrally. One specimen showed 3 distinct dorsal transverse breaks, while another was rather angulate and had orange extremities and a marginal peripheral line.

## Simniinae SCHILDER, 1927

1932. Volvinae SCHILDER, Proc. Malacol. Soc. London, 20: 47 (as Volvini)

1956. Volvinae ALLAN, Cowry shells of world seas, p. 126

1958. Volvinae COTTON, Journ. Malacol. Soc. Austral., 2: 11

Species of Simniinae have elongate-fusiform and depressed shells with produced extremities, shells are unicoloured, occasionally with a median band, smooth or transversely striate; a dorsal carina is obsolete or absent. The columella lacks the anterior terminal ridge, labial teeth are obsolete or absent, columella edentulous, fossula either narrow or absent. The radula is similar to that of the Ovulinae.

Species of Simniinae are associated with reef-dwelling gorgonians and alcyonarians, and sometimes adopt the

colour of the host coral; the majority of species is confined to deeper water.

### *Volva* RÖDING, 1798

*Volva* RÖDING, 1798, Mus. Bolten., p. 21. Type species by T *Bulla volva* LINNAEUS, 1758.

1810. *Radius* MONTFORT, Conch. Syst., 2: 626 (Type species by OD *Bulla volva* LINNAEUS, 1758)

1840. *Birostra* SWAINSON, Treat. Malacol., p. 325 (Type species by OD *Bulla volva* LINNAEUS, 1758)

Shells are pyriform, inflated, extremities greatly produced, dorsum spirally striate; labial lip convex, labial teeth absent or obsolete, columella edentulous, fossula absent.

The radula of the type species (*fide* BARNARD, 1963) has roundly pentagonal rhachidians with a moderately short central cusp and a small accessory denticle at either side; the laterals have a large main cusp and one side cusp on the cutting edge, and a large and slender basal peg; marginals comb-like and similar to those of other genera of Ovulidae.

### *Volva volva* (LINNAEUS, 1758)

(Plate 50, Figures 9, 9a)

1758. *Bulla volva* LINNAEUS, Syst. Nat., ed. 10, p. 725, no. 328

1798. *Volva textoria* RÖDING, Mus. Bolten., p. 22, no. 259

1811. *Ovula striata* LAMARCK, Ann. Mus. Hist. Nat., 16: 113 ("Coast of Brazil" — erroneous)

1931. *Volva volva cumulata* IREDALE, Rec. Aust. Mus., 18: 222 (nom. nud.)

1935. *Volva volva cumulata* IREDALE, Aust. Zool., 8: 104

1937. *Volva volva surabajensis* SCHILDER, Ing. Ned. Indie, 4: 205 (fossil from Soerabaja)

1941. *Volva (Volva) volva lemurica* SCHILDER, Arch. Molluskenk., 73: 110 (nom. nov. pro *V. volva* var. MELVILL, 1909)

1961. *Volva volva habei* OYAMA, Venus : Japan. Journ. Malacol., 21: 288; text figs. 3, 4

1963. *Volva volva* (LINNAEUS), BARNARD, Ann. South Afr. Mus., 47 (1): 56; fig. 6 d (radula)

**Shell:** Large and fusiform, inflated centrally, extremities produced into long and slender canals; pinkish-white in colour, margins white, interior of aperture yellowish-brown. Sculptured with *ca.* 80 transverse striae which become obsolete centrally on dorsum; outer lip convex, ornamented with *ca.* 14 very obsolete blunt denticles, columella edentulous. Anterior terminal ridge, first funiculum and posterior outlet absent, second funiculum projecting, fossula absent.

Juvenile shells are white in colour, fragile, extremities are greatly produced and slender, and the transverse striae appear as distinct elevated cords on the dorsum.

L: 77–85 mm; W: 28–30%

**Type Locality:** Ad Jamaica (Error) ["Ceylon," IREDALE, 1935]

**Habitat:** In 15 fathoms, on coral rubble and sand substratum. Rare.

**Distribution:** North and West Viti Levu. — From East Africa through the tropical Indo-Pacific to Japan and the Fiji Islands.

### *Phenacovolva* IREDALE, 1930

*Phenacovolva* IREDALE, 1930, Mem. Qld. Mus., 10: 85. Type species by OD *P. nectarea* IREDALE, 1930 = *Bulla birostris* LINNAEUS, 1767

1817. *Radius* SCHUMACHER, Ess. nouv. syst., p. 259 (Type species by M. R. *brevirostris* SCHUMACHER, 1817 = *Bulla birostris* LINNAEUS, 1767) [non MONTFORT, 1810]

1956. *Phenacolepas* (sic) IREDALE, ALLAN, Cowry shells of world seas, p. 134 [non PILSBRY, 1891]

Shells are moderately small, slender and fusiform, with shorter extremities than in *Volva* s. str.; dorsum smooth or striate, unicoloured or with a light coloured median band. Labial and columellar lips edentulous, fossula absent.

The radula of *Phenacovolva aurantia* (SOWERBY, 1889) [= ? *P. birostris* (LINNAEUS, 1767) or *P. sowerbyana* (WEINKAUFF, 1881)] as figured by BARNARD (1963), is dissimilar to the radula of *Volva* s. str. The rhachidians are triangular, the central cusp is solid but short and flanked by moderately solid side cusps; the laterals and marginals are similar to those of *Volva volva* (LINNAEUS).

*Phenacovolva* contains a compact group of Recent species which appear to be separable from *Volva* on the basis of shell morphology and radula features.

### *Phenacovolva birostris* (LINNAEUS, 1767)

(Plate 50, Figure 10)

1767. *Bulla birostris* LINNAEUS, Syst. Nat., ed. 12, p. 1182, no. 371

1817. *Radius brevirostris* SCHUMACHER, Ess. nouv. syst., p. 259

1855. *Volva rosea* A. ADAMS, Proc. Zool. Soc. London for 1854: 130; pl. 28, fig. 9

1930. *Phenacovolva nectarea* IREDALE, Mem. Qld. Mus. 10: 85; pl. 9, fig. 6

**Shell:** Fusiform and rostrate, dark pink in colour, ornamented with a white median transverse band; margins white, extremities brown. Dorsum without a carina, sculptured with *ca.* 50 transverse striae across dorsum; aperture dilated anteriorly. Labial lip flattened and curved, teeth very obsolete and numbering *ca.* 20 in the Fiji specimen; anterior columellar terminal ridge absent, first funiculum obsolete, second funiculum projecting and

sculptured with 4 denticles. Interior of columella finely striate, second posterior outlet prominent, fossula absent. L: 20.0 mm; W: 22%

**Type Locality:** Ad Javam.

**Habitat:** Dredged in 15 fathoms on coral. — Rare.

**Distribution:** From Indonesia to Japan and the Fiji Islands.

**Discussion:** SCHILDER (1966a) pointed out that the type specimen of LINNAEUS' *Bulla birostris* is the same species as *Radius brevirostris* SCHUMACHER, and that the *Volva birostris* auctt. is the species *V. longirostrata* (SOWERBY, 1828). The presence of both species among the types of *Bulla birostris* in the Linnean collection was responsible for the confusion.

The species is known from Fiji from one complete and one partially broken specimen; both, however, are more slender than the usual specimens of *Phenacovolva birostris*, and are also striate across the dorsum along its entire length.

*Phenacovolva gracilis* (ADAMS & REEVE, 1848)

(Plate 51, Figure 11)

1848. *Ovulum gracile* ADAMS & REEVE, Zool. Voy. Sam., p. 22; plt. 6, figs. 11 a, 11 b, 11 c

**Shell:** Fusiform and rostrate, pinkish-white in colour, generally with a white median transverse band; an orange coloured line encircles the margins. Dorsum sculptured with ca. 70 transverse striae which become somewhat obsolete centrally. Labial lip convex and curved, ornamented with 15 very obsolete denticles; first funiculum absent, second funiculum projecting, sculptured with 5 denticles; interior of columella finely striate, fossula absent.

L: 20.0 mm; W: ? 26%

**Type Locality:** East coast of Borneo.

**Habitat:** Dredged in 15 fathoms on coral rubble substrate. Rare.

**Distribution:** West off Viti Levu. — From Indonesia to Japan and the Fiji Islands.

**Discussion:** A small portion of the extremities in the Fiji specimen is missing and the width ratio of 26% appears

therefore somewhat inflated. This species is rather similar to *Phenacovolva birostris* and differs mainly in colouring, the convex labial lip and more dilated aperture. SCHILDER (1932) states that the labial lip of *P. gracilis* is edentulous, but in the Fiji specimen the labial denticles are obsolete, but can nevertheless be counted.

(*Pellasmnia*) (IREDALE, 1931, *nud.*)

SCHILDER, 1939

*Pellasmnia* SCHILDER, 1939, Arch. Molluskenk. 71: 195. Type species by OD *Ovulum angasi* REEVE, 1865

1931. *Pellasmnia* IREDALE, Rec. Aust. Mus., 18: 222 (*nud.*)

1939. *Pellasmnia* SCHILDER, Arch. Molluskenk., 71: 195 (first valid description)

Shells of the subgenus are fusiform with pointed extremities, smooth and lack a dorsal carina; dorsum is unicoloured, extremities with or without dark stains. Labial lip reflexed, teeth generally obsolete, columella edentulous, fossula narrow.

The radula of the type species (*fide* SCHEPMAN, 1909) differs in features from those of other genera of Simniinae. The rhachidians are somewhat quadrate, the central cusp is broad and long, and is flanked by two accessory denticles at either side.

*Phenacovolva* (*Pellasmnia*) *philippinarum*

(SOWERBY, 1849)

(Plate 51, Figure 12)

1849. *Ovulum philippinarum* SOWERBY, Proc. Zool. Soc. London, 16: 136

1877. *Volva carpenteri* DUNKER, Malakol. Blätter, 24: 75

1877. *Volva adamsii* DUNKER, Malakol. Blätter, 24: 75

1882. *Radius carpenteri* DUNKER, Ind. Moll. Mar. Jap., p. 102; plt. 13, figs. 1, 2

1882. *Radius adamsii* DUNKER, Ind. Moll. Mar. Jap., p. 102; plt. 13, figs. 3, 4

1889. *Ovulum (Birostra) haynesi* SOWERBY, Journ. Lin. Soc. London, 20: 397; plt. 25, figs. 1, 2

1909. *Amphiperas (Radius) philippinarum* (SOWERBY), SCHEPMAN, Siboga Exp., 49b: 144; plt. 15, fig. 6 (radula)

## Explanation of Plate 52

Figures 20 and 20a: *Trivirostra producta* (GASKOIN). Fiji. (x 3.2 and 3.0, respectively)

Figure 21: *Trivirostra pellucidula* (REEVE). Fiji. (x 5.0)

Figure 22: *Lachryma sulcifera* (SOWERBY). Fiji, granulose specimen. (x 8.0)

Figure 22a: *Lachryma sulcifera* (SOWERBY). Fiji, smooth specimen (x 8.0)

Figure 23: *Primovula margarita* (SOWERBY). Holotype, B. M. N. H. Reg. No. 1967613/1. Length: 13.8 mm (holed).

Figure 24: *Primovula margarita* (SOWERBY). Paratype B. M. N. H. Reg. No. 1967613/2. Length 8.2 mm

Figure 25: *Primovula margarita* (SOWERBY). Paratype B. M. N. H. Reg. No. 1967613/3. Length 12.1 mm (holed).

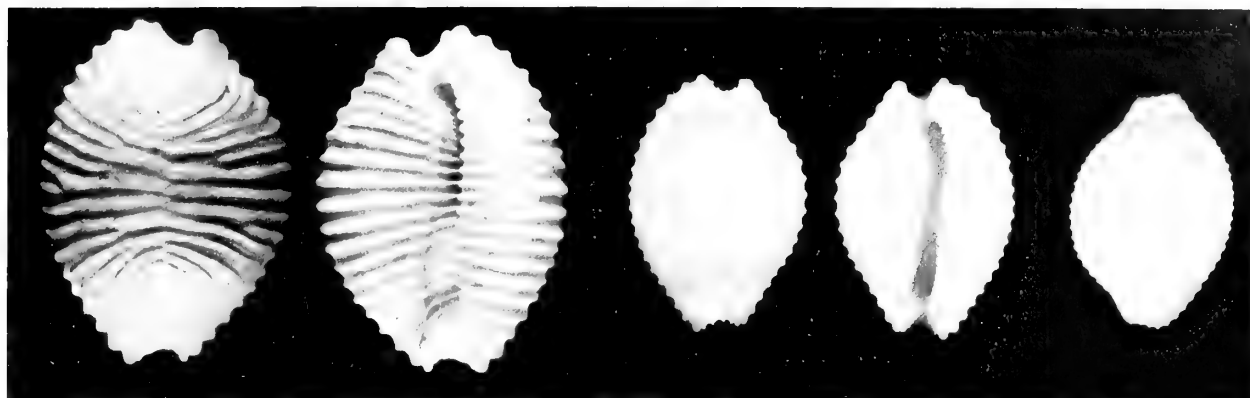


Figure 20

Figure 20 a

Figure 21



Figure 21 a

Figure 22

Figure 22 a

Figure 23



Figure 24

Figure 25



**Shell:** Elongate-fusiform, striate at extremities, dorsal carina absent; dorsal colour salmon-pink, labial margin light pink, basal colour pinkish-white, extremities dark brown. Labial lip flattened and smooth, anteriorly somewhat recurved, anterior columellar terminal ridge and first funiculum absent, second funiculum moderately projecting, second posterior outlet prominent, fossula absent. L: 33.0 mm; W: 21%

**Type Locality:** Philippines.

**Habitat:** On small, black-spotted coral, in shallow water. Rare.

**Distribution:** South Viti Levu. — From Indonesia to Japan and the Fiji Islands.

#### Eocypraeinae SCHILDER, 1924

1929. Jenneriinae THIELE, Handb. syst. Weichtierk., p. 269  
1939. Sulcocypraeinae SCHILDER, Arch. Molluskenk., 71: 191

Species of Eocypraeinae are characterized by pyriform to ovate shells which are either smooth, transversely ribbed or pustulose; teeth on both lips are well developed, aperture is narrow, columella is ungrooved and the fossula is smooth.

The radulae of living species differ appreciably from those of other families of Cypraeacea. The laterals are broad, with numerous long and slender cusps; marginals are slender and have fewer cusps than have species of Ovulinae. There is an additional smaller edentulous plate which connects the laterals with the marginals; a similar connecting plate is present in the radula of Pediculariidae.

The subfamily contains numerous fossil species but only 2 living relics, i. e. the Indo-Pacific *Pseudocypraea adamsonii* (SOWERBY, 1832) and the West American *Cypropterina pustulata* (LIGHTFOOT, 1786). Living species of Eocypraeinae inhabit crevices and the underside of coral rocks.

#### *Pseudocypraea* SCHILDER, 1927

*Pseudocypraea* SCHILDER, 1927, Arch. Naturgesch., 91A: 71. Type species by OD *Cypraea adamsonii* SOWERBY, 1832

The genus is monotypic and contains only the one Recent Indo-Pacific species.

#### *Pseudocypraea adamsonii* (SOWERBY, 1832)

(Plate 51, Figure 14)

1832. *Cypraea adamsonii* SOWERBY, Conch. Illust., Cat. Cyp., p. 11, figs. 7, 7a  
1879. *Cypraeovula adamsonii* GRAY, GARRETT, Journ. Conch., 2: 121 (animal description)

1929. *Pseudocypraea adamsonii* (SOWERBY), THIELE, Handb. syst. Weichtierk., p. 270, fig. 285 (radula)

1961. *Pseudocypraea adansonii* (sic) (SOWERBY), HABE, Col. illust. shells Japan, 2: 41; plt. 19, fig. 2

**Shell:** Small and pyriform, whitish in colour, ornamented with 4 - 5 brown spots on dorsum which are generally arranged in 3 zones, and orange-brown transverse streaks on labial margin. Dorsum sculptured with 35 - 40 coarse and flat dorsal transverse cords. Columellar margin rounded, aperture narrow, base convex, labial teeth strong and produced to margin, numbering from 19 to 23; columellar teeth thickened at aperture, extending to margin, numbering from 18 to 20, interior of columella striate.

L: 8 - 10 mm; W: 58 - 62%

**Type Locality:** Mauritius.

**Habitat:** Under coral rocks, in shallow water. — Rare.

**Distribution:** South Viti Levu. — From Mauritius through the tropical Indo-Pacific to Japan, Fiji and the Tuamotu Archipelago.

**Discussion:** SCHILDER (1941) does not report the species from the Indian Ocean. I have seen a specimen from Mauritius (coll. E. Couacaud) which appears to confirm the correctness of SOWERBY's type locality.

#### PEDICULARIIDAE H. & A. ADAMS, 1854

The family contains a group of species with small cap-shaped, unicoloured shells with a flaring margin, striate dorsum with minutely granulose interstices, sharply edged lips and a projecting or covered spire. Juvenile shells are, however, subglobular with a projecting spire and denticulate lips.

The radula is similar to that of Eocypraeinae (Ovulidae); the rhachidians are roughly rectangular, the central cusp is moderately long and flanked by 4 - 7 side denticles; laterals are strong, main cusps large, with 3 - 4 denticles on the cutting edge; marginals are slender and have 2 - 4 finger-like cusps and a shorter claw-like cusp at either side.

Pediculariidae are sessile on stylasterid corals, and their shell-margins correspond to the general outline of the host coral on which they live, and also approximate it in colouring. Representatives of Pediculariidae are found in all major seas.

**Discussion:** SWAINSON (1840) established *Pedicularia* with the Mediterranean *P. sicula* SWAINSON, 1840, as type species. *Pediculariella* THIELE, 1925, was created for the Californian species *Pedicularia californica* NEWCOMB, 1864. IREDALE (1935) introduced *Pediculariona* for the Australian species *Pedicularia stylasteris* HEDLEY, 1903,

because the shells "superficially differ." Pediculariidae contain only 10 species, some being possible synonyms; they are so similar that some species are being separated on the basis of the number of striations. SCHILDER (1944) found the radula of the Pacific *Pedicularia pacifica* PEASE, 1865, to be similar to the radula of the Mediterranean *P. sicula* SWAINSON, as figured in THIELE (1929). The shells, anatomy and radula features of the 10 Recent species of Pediculariidae are all so basically alike that one would tend to question the taxonomic value of 2 genera created on a geographic basis alone. So far only one fossil species has been recorded: *P. deshayesiana* SEGUENZA, 1865.

*Pedicularia* SWAINSON, 1840

*Pedicularia* SWAINSON, 1840, Treat. Malac., pp. 244, 357. Type species by M. *P. sicula* SWAINSON, 1840

1844. *Thyreus* PHILIPPI, Enum. Moll. Sic. 2: 92 (Type species by M. *T. paradoxus* PHILIPPI, 1844 = *Pedicularia sicula* SWAINSON, 1840)

1863. ? *Dentiora* PEASE, Proc. Zool. Soc. London, p. 240 (Type species by M. *D. rubida* PEASE, 1863 = spec. juv. *Pedicularia pacifica* PEASE, 1865)

1925. *Pediculariella* THIELE, KÜCKENTHAL, Handb. Zool., 5: 88 (Type species by OD *Pedicularia californica* NEWCOMB, 1865)

1935. *Pediculariona* IREDALE, Aust. Zool., 8: 101 (Type species by OD *Pedicularia stylasteris* HEDLEY, 1903 = *P. pacifica* PEASE, 1865)

The genus contains only 9-10 species which have a world-wide distribution. One cannot describe morphological or anatomical differences between genera or subgenera where such do not exist. SCHILDER (1939) in his diagnosis of genera of Pediculariidae comments: "Unterschiede unsicher; Anatomie abweichend."

*Pedicularia pacifica* PEASE, 1865

(Text figure 4)

1863. ? *Dentiora rubida* PEASE, Proc. Zool. Soc. London for 1862: 240 (spec. juv.?)

1865. *Pedicularia pacifica* PEASE, Proc. Zool. Soc. London, p. 516

1868. *Pedicularia pacifica* PEASE, Amer. Journ. Conch., 4: 96; plt. 11, figs. 17, 18

1903. *Pedicularia stylasteris* HEDLEY, Mem. Aust. Mus., 4: 342, figs. 69, 70

1944. *Pedicularia pacifica* PEASE, SCHILDER, Ark. Zool. 36A: 29-31 (animal, radula, veligers)

1965. *Pedicularia pacifica* PEASE, KAY, Bull. Brit. Mus. (Nat. Hist.) Zool. Suppl., 1: 84; plt. 14, figs. 13, 14 (lectotype 6 x 3 mm)

**Shell:** Small, irregularly ovate or oblong-ovate, reddish-pink to purple in colour. Dorsum sculptured with numerous concentric ribs and intersecting striae which are alternately coarse and fine. Aperture wide open, margins sharply edged, teeth obsolete in adult specimens; spire visible and clathrate or concealed.

L: 5.5 - 6.2 mm.

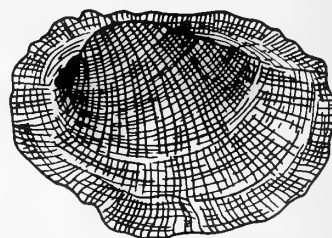


Figure 4

*Pedicularia pacifica* PEASE  
(after SCHILDER, 1931)

**Type Locality:** Central Pacific (Apaian Island, PEASE, 1868) [= Abaiang Island, Gilbert Islands]

**Habitat:** Unknown (sessile on coral, *vide* SCHILDER, 1931).

**Discussion:** The species is known from only 2 beach-worm and partly broken specimens; being unsuitable for photography, a drawing of the species is given from SCHILDER, 1931.

The species has occasionally been reported from the Hawaiian Islands, but according to KAY (1965) it does not live there.

TRIVIIDAE TROSCHEL, 1863

1927. ERATOIDAE SCHILDER, Arch. Naturgesch. 91: 1 (as Eratoinae)

1932. ERATOIDAE SCHILDER, Proc. Malacol. Soc. London, 20: 46

Shells of Triviidae are moderately small or very small, ovate, round and inflated, sometimes biconical, unicoloured, spotted or banded; they are smooth or sculptured with transverse ribs, granules and a dorsal groove. The spire is covered or projecting, aperture wide or narrow, lips denticulate.

The animals of Eratoinae have an open siphon, i.e. grooved, whereas animals of the Triviinae have a closed, tube-like siphon; in other respects they approximate the animals of Cypraeidae. The rhachidians of the radula are either quadrate or trapezoidal, with a larger central cusp and up to a dozen side denticles; laterals are hook-

like, simple, and with or without denticles on the cutting edge; marginals are claw-like, inner marginal occasionally with a small denticle.

Triviidae have a world wide distribution and range farther into colder waters than the Ovulidae. Tropical Triviidae share the same habitat with the Cypraeidae; they are reef-dwellers and live in crevices or on the underside of coral blocks.

**Discussion:** SCHILDER (1933) pointed out that the anatomy of Eratoinae hardly differs from that of the Triviinae, and that the radulae are almost identical. All indications are that Eratoinae and Triviinae are closely related, the Eratoinae being the more primitive group of Triviidae from which Recent Triviinae have diverged.

#### Triviinae TROSCHER, 1863

1932. Eratoinae SCHILDER, Proc. Malacol. Soc. London, 20: 46

Species of Triviinae have ovate or round, inflated shells which are unicoloured or spotted; the transverse dorsal ribs, which may or may not be interrupted by a dorsal groove, extend onto the base and into the aperture; the dorsal ribs are occasionally noded near the dorsal groove. The spire is generally covered in adult specimens, aperture is linear and sometimes wide, and both lips are denticulate; the columella generally extends deep into the aperture.

Triviinae have a world wide distribution and live in the intertidal zone and in deeper water.

#### *Trivirostra* JOUSSEAUME, 1884

*Trivirostra* JOUSSEAUME, 1884, Bull. Soc. Zool. France, 9: 100. Type species by SD (ROBERTS in TRYON, 1885) *Cypraea scabriuscula* GRAY, 1827 = ? *Cypraea oryza* LAMARCK, 1811

Shells small, generally ovate, white in colour; transversely ribbed, dorsal groove moderately short, interstices of ribs granulose. Sides rounded, aperture narrow, fossula broad, columella intruding deeply into the aperture.

The radula of *Trivirostra* differs in some features from the radula of *Trivia* BRODERIP, 1837 [type species *T. monacha* (DA COSTA, 1778)]. The rhachidians of *Trivia* are quadrate, but are trapezoidal in *Trivirostra*, and the basal pegs are more prominent. The laterals of *Trivirostra* have small accessory denticles on the cutting edge, similar to the laterals of *Trivia arctica* (PULTENEY, 1799), whereas in *Trivia monacha* the laterals lack the small denticles; the marginal teeth of *Trivirostra* are simple and hook-like, and the inner marginal may on occasion have a very small denticle.

Species of the genus inhabit crevices of coral rocks,

and are frequently found on marine benches with a maximum of algal matting.

#### *Trivirostra (Trivirostra) edgari* (SHAW, 1909)

(Plate 51, Figure 17)

1849. *Cypraea grando* GASKOIN, Proc. Zool. Soc. London, 16: 96 (non POTIEZ & MICHAUD, 1838)  
 1909. *Trivia edgari* SHAW, Proc. Malacol. Soc. London, 8: 310 (nom. nov. pro *Cypraea grando* GASKOIN, 1849)  
 1917. *Trivia oryza* ODHNER, Svens. Akad. Handl. 52: 53; plt. 2, figs. 52, 53; text fig. 12 (shell and radula of *Trivirostra oryzoidea* IREDALE, 1935) [non *Trivia oryza* LAMARCK, 1811]  
 1935. *Trivirostra oryzoidea* IREDALE, Aust. Zool., 8: 101 (nom. nov. pro *Trivia oryza* ODHNER, 1917)  
 1944. *Trivirostra edgari insularum* SCHILDER, Ark. Zool., 36A: 14 (descr. radula)  
 1944. *Trivirostra edgari tomlini* SCHILDER, Ark. Zool., 36A: 14

**Shell:** Small, broadly ovate, extremities produced and broad; white in colour throughout. Sculptured with coarse and elevated transverse ribs and a broad but short dorsal groove which does not interrupt the 23 - 26 dorsal ribs; interstices of ribs are minutely crenulate. Aperture almost central, labial lip with 20 - 23 denticles, columellar lip with 16 - 19 denticles; the interior of the columella extends in a flatly convex arc, and the fossula is moderately narrow and concave and does not protrude towards the labial wall as in *Trivirostra oryza*.

L: 5.9 - 6.6 mm; W: 73 - 79%; H: 66 - 69%

**Type Locality:** Manilla (Manila, Philippine Islands).

**Habitat:** Under coral rocks, in shallow water.

Moderately rare.

**Distribution:** South Viti Levu, Vanua Levu and Taveuni. - From East Africa through the tropical Indo-Pacific to Japan, Hawaii and the Tuamotu Archipelago.

**Discussion:** Fijian specimens of *Trivirostra edgari* are rather similar in dimensions, teeth and dorsal rib count to the East African race *T. edgari tomlini* SCHILDER.

#### *Trivirostra (Trivirostra) exigua* (GRAY, 1831)

(Plate 51, Figure 18)

1831. *Cypraea exigua* GRAY, Zool. Misc., 1: 35  
 1833. *Cypraea tremzsa* DUCLOS, Mag. de Zool., plt. 25  
 1845. *Cypraea gemmula* GOULD, Proc. Boston Soc. Nat. Hist., 2: 27  
 1868. *Trivia corrugata* PEASE, Amer. Journ. Conch., 4: 95; plt. 11, figs. 14, 15  
 1914. *Trivia exigua* var. *alba* SOWERBY, Proc. Malacol. Soc. London, 11: 10  
 1923. *Trivia exigua* (GRAY) VAYSSIÈRE, Ann. Mus. Hist. Nat. Marseilles, 18: 86 - 87; plt. 14, figs. 209 - 212 (anatomy)  
 1933. *Trivirostra exigua hyalina* SCHILDER, Zool. Anz., 102: 290

1964. *Cypraea (Trivia) gemmula* GOULD, JOHNSON, U.S.  
Nat. Mus. Bull. No. 239: 82; plt. 7, fig. 10 (lectotype)

**Shell:** Small, roundly pyriform, extremities produced; pinkish-white in colour, ornamented with 2 - 5 pink spots on dorsum, dorsal ribs occasionally pink in colour. Sculptured with 16 - 29 coarse dorsal ribs and an impressed dorsal groove which does not separate the ribs; the ribs are sometimes thickened near the margins of the dorsal groove and interstices of ribs are finely crenulate. Aperture is slightly off-central, labial teeth number from 20 to 23, columellar teeth from 18 to 19; fossula is concave, but extends only slightly towards the labial wall. L: 4.2 - 4.5 mm; W: 66 - 71%; H: 60 - 63%

**Type Locality:** None ("New South Wales," SOWERBY, [1832]).

**Habitat:** Under coral rocks, in shallow water.  
Moderately rare.

**Distribution:** South Viti Levu. — Throughout the tropical Pacific.

*Trivirostra (Trivirostra) hordacea* (KIENER, 1843)

(Plate 51, Figure 19)

1827. ? *Cypraea scabriuscula* var. *minor* GRAY, Zool. Journ., 3: 364  
1843. *Cypraea hordacea* KIENER, Spéc. gén. icon. coq. viv., p. 149; pl. 54, figs. 5, 5 a  
1845. *Cypraea insecta* MIGHELS, Proc. Boston Soc. Nat. Hist., 2: 24  
1870. ? *Cypraea sandwichensis* SOWERBY, Thes. Conch., 4: 47, expl. to plt. 35  
1870. ? *Cypraea sandwichensis* SOWERBY, Thes. Conch., 4: 57  
1912. *Trivia desirabilis* IREDALE, Proc. Malacol. Soc. London, 10: 226; plt. 9, figs. 8, 9 (Kermadec Island)  
1932. *Trivirostra hordacea* (KIENER), SCHILDER, Zool. Anz., 100: 226; fig. 2 (radula)

**Shell:** Small, subcylindrical and elongate, extremities hardly produced, dorsum depressed; white in colour throughout. Sculptured with fine and numerous transverse ribs which number from 26 to 32; the dorsal groove is long and interrupts the dorsal ribs; interstices of ribs are finely crenulate. Aperture is off-central, outer lip moderately narrow and with 22 - 23 labial teeth; the columella is rather broad and sculptured with 19 - 21 teeth. Fossula broad and concave, only slightly extending towards the labial wall, posterior of columellar lip somewhat truncated.

L: 3.8 - 4.1 mm; W: 64 - 66%; H: 52 - 58%

**Type Locality:** Mers de l'Inde, les côtes de l'île Bourbon [= Réunion Island].

**Habitat:** Under coral rocks, in shallow water. — Rare.

**Distribution:** North and South Viti Levu. — From East

Africa through the tropical Indo-Pacific to Hawaii and the Tuamotu Archipelago.

*Trivirostra (Trivirostra) oryza* (LAMARCK, 1811)

(Plate 51, Figure 15)

1811. *Cypraea oryza* LAMARCK, Ann. Mus. Hist. Nat., 16: 104  
1817. *Cypraea nivea* DILLWYN, Desc. cat. Rec. shells, 1: 466  
1817. ? *Cypraea sulcata* var.  $\beta$  DILLWYN, Desc. cat. Rec. shells, 1: 466  
1827. ? *Cypraea scabriuscula* GRAY, Zool. Journ., 3: 364  
1843. *Cypraea intermedia* KIENER, Spéc. gén. icon. coq. viv., p. 143; plt. 52, figs. 2, 2 a (non GRAY, 1824)  
1908. *Trivia oryza* (LAMARCK), BERGH, Semp. Reise Arch. Philipp., 9: 144; plt. 11, figs. 27 - 37 (anatomy)  
1909. *Trivia oryza* forma *minor* SCHEPMAN, Siboga Exped., 49b: 137 (non GRAY, 1827)  
1932. *Trivirostra oryza triticum* SCHILDER, Foss. Cat., 1/55: 101  
1932. *Trivirostra oryza turneri* SCHILDER, Foss. Cat., 1/55: 101

**Shell:** Small and ovate, extremities generally blunt but sometimes moderately produced; white in colour throughout. Dorsum is ornamented with close-set fine transverse ribs, numbering from 30 to 45; the dorsal groove is either moderately deep or shallow and, in the majority of specimens examined, does not separate the dorsal ribs. Sides are rounded, base convex, aperture narrow, labial lip fairly straight and sculptured with 19 - 26 denticles. Interior of columella curved, fossula broad and concave, and extending towards the labial wall.

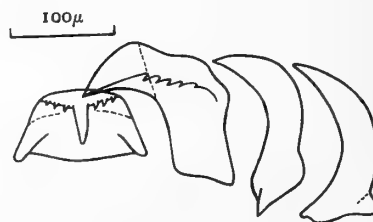


Figure 5

*Trivirostra oryza* (LAMARCK)  
Fiji Islands  
Half row of radular teeth

**Animal:** Sole and dorsum of foot brown, finely veined with white; mantle light grey, flecked with blackish-brown, becoming dark brown towards the mantle margin. Papillae few, short and fringed, yellow in colour. The siphon is cylindrical, closed and tubular, yellow in colour and papillate on the sides. Tentacles are short and blunt at

distal end, brown in colour, flecked with white; eyes black and ringed with white.

**Radula:** Radular ribbon white, 3.9 mm long and 0.57 mm wide in an animal with a shell 8.0 mm in length; the ribbon contains 49 rows (plus 4 nascentes) of teeth. Rhachidians are trapezoidal, 0.13 mm wide and 0.06 mm long, central cusp is long and flanked by 3 or 4 small denticles; base of plate with a large basal peg on either side; laterals are large and have *ca.* 5 denticles on the cutting edge; marginals simple and curved.

L: 5 - 10 mm; W: 66 - 78%; H: 57 - 62%

**Type Locality:** Timor.

**Habitat:** On reefs, under coral rocks, in shallow water. Common.

**Distribution:** Throughout the Fiji Islands. - From the Gulf of Oman through the tropical Indo-Pacific to the Tuamotu Archipelago.

**Discussion:** The species is extremely variable and diagnostic characters show a rather long range of variation. Well over 100 specimens were measured, and in *ca.* 90% of them the labial teeth were 1.2 - 1.3 times as numerous as the columellar teeth.

#### *Trivirostra (Trivirostra) species*

(Plate 51, Figure 16)

**Shell:** Similar to *Trivirostra oryza* (LAMARCK), but differs in being more roundly pyriform with produced extremities and a shallow dorsal groove which does not interrupt the dorsal ribs; the aperture is almost central, both columellar and labial lips are curved, and are sculptured with 28 and 22 denticles respectively. The fossula is extremely broad, concave and coarsely ribbed, and extends deeply towards the labial wall.

L: 8.3 mm; W: 72%; H: 60%; dorsal ribs: 38

**Habitat:** Under coral rocks, in shallow water. - Rare.

**Distribution:** South Viti Levu. - ? Indonesia.

**Discussion:** The species is known from one live-collected specimen which seems to be separable from *Trivirostra oryza*. It resembles the species *T. scabriuscula* (GRAY), as of authors, and is depicted under this name in several monographs on the family.

#### (*Dolichupis*) IREDALE, 1930

*Dolichupis* IREDALE, 1930, Mem. Qld. Mus., 10: 83. Type species by OD *Cypraea producta* GASKOIN, 1836

1931. *Trivellona* IREDALE, Rec. Aust. Mus., 18: 221 (Type species by M *T. excelsa* IREDALE, 1931 = *Cypraea producta* GASKOIN, 1836)

Shells are small, ovate, white in colour, extremities produced, sides broad and somewhat angulate; the dorsal ribs are coarse and prominent, interstices granulose, dorsal groove is absent.

**Discussion:** *Dolichupis* was established by IREDALE (1930) for "the forms with produced extremities." This short diagnosis is misleading for a generic assignment, in view of the occurrence of both produced and blunted extremities in the same species. SCHILDER (1939) treated *Dolichupis* as a subgenus of *Pusula* JOUSSEAUME, 1884. The type species of *Dolichupis*, however, seems morphologically closer to *Trivirostra* than to *Pusula radians* (LAMARCK, 1811), the type species of *Pusula*; the latter species is brownish with lighter coloured dorsal ribs which are pustulose and widely spaced, and the extremities are blunter than in *Dolichupis*. *Dolichupis* differs from *Trivirostra* mainly in the more produced extremities, broad and angulate sides and obsolete dorsal groove; all other characters are variable between species of the two groups.

#### *Trivirostra (Dolichupis) pellucidula* (REEVE, 1846)

(Plate 52, Figures 21, 21 a)

1846. *Cypraea pellucidula* REEVE, Conch. Icon., *Cypraea*, pl. 26, sp. 153 (March 1846)

1846. *Cypraea pellucidula* GASKOIN, Proc. Zool. Soc. London, p. 23 (May 1846)

1881. *Cypraea pellicula* (sic) WEINKAUFF, Conch. Cab., ed. 2, p. 161; pl. 43, figs. 1, 4

1932. *Trivirostra pellucidula natalensis* SCHILDER, Foss. Cat., 1/55: 102

**Shell:** Small, roundly pyriform, extremities produced; white in colour throughout. Sculptured with 26 - 30 fine dorsal ribs, dorsal groove is absent or very obsolete, interstices minutely crenulate; sides are rounded, aperture slightly off-central and curved. Labial teeth number from 26 to 28, columellar teeth from 20 to 22; fossula is very broad and concave and extends towards the labial wall.

L: 6.0 - 6.8 mm; W: 69 - 71%; H: 58 - 60%

**Type Locality:** South Pacific.

**Habitat:** In 15 fathoms, on broken coral substratum.

Rare.

**Distribution:** West off Viti Levu. - From East Africa through the tropical Indo-Pacific to Japan, Hawaii and the Tuamotu Archipelago.

**Discussion:** SCHILDER (1941) placed *Trivirostra pellucidula* in the subgenus *Trivirostra s. str.*; if the subgenus *Dolichupis* is to contain triviid species with produced extremities and an obsolete dorsal groove, then the species *T. pellucidula* clearly belongs to *Dolichupis*.

GASKOIN is generally credited with the authorship of *Trivirostra pellucidula*, but REEVE's publication of the species name has 2 months priority over GASKOIN's.

*Trivirostra (Dolichupis) producta* (GASKOIN, 1836)

(Plate 52, Figures 20, 20a)

1836. *Cypraea producta* GASKOIN, Proc. Zool. Soc. London for 1835: 200  
 1837. *Cypraea producta* GASKOIN, SOWERBY, Conch. Illust., fig. 155 (holotype)  
 1871. *Trivia candidula* ANGAS, Proc. Zool. Soc. London, p. 94 (non GASKOIN, 1836)  
 1923. *Trivia producta* (GASKOIN), VAYSSIÈRE, Ann. Mus. Hist. Nat. Marseilles, 18: 88-89; plt. 9, figs. 115-121 (anatomy)  
 1931. *Trivellona excelsa* IREDALE, Rec. Aust. Mus., 18: 221; plt. 14, figs. 13, 14

**Shell:** Small, ovate and humped, sides broadened and slightly angulate; white in colour throughout. Sculptured with 20-26 strong, elevated and sharply cut transverse ribs which cross the centre of the dorsum and descend towards the margins; a dorsal groove is absent, but occasionally faintly impressed, interstices of ribs broad and crenulate. Base flattened, aperture almost central and of medium width, labial lip broad and with 22-24 denticles; columella with 19-23 denticles, interstices of ribs with small axial riblets. Posterior outlet sharply cut, fossula very broad, concave and extending towards the labial wall.

**Animal:** Sole of foot white, dorsum of foot translucent white, ornamented with iridescent white spots; mantle white, papillae tufted, cream-coloured, and extending half-way up the mantle; the mantle margins are speckled with grey. Tentacles creamy-white; siphon greyish-white, flecked with darker grey and almost as long as the shell itself.

L: 10-15 mm; W: 70-73%; H: 54-56%

**Type Locality:** None ("Unsang, East coast of Borneo," *vide* ADAMS & REEVE, 1848).

**Habitat:** In 15-16 fathoms, on coral rubble substratum. Moderately rare.

**Distribution:** West off Viti Levu. - From Indonesia to the Tuamotu Archipelago.

**Discussion:** The holotype of *Trivellona excelsa* IREDALE, 1931, preserved in the Australian Museum, Sydney, is a large (18.0 mm), dead-collected, anteriorly somewhat worn specimen of *Trivirostra producta* (GASKOIN).

SOWERBY (1870) reports the species from Agulhas Bank; if this record is correct, then the species' range extends as far westward as South Africa.

Eratoinae SCHILDER, 1927

Species of this subfamily differ from Triviinae in having biconical, marginellid shells with a projecting and broad spire and an angulate aperture. Shells are unicoloured or banded, dorsally grooved, smooth, granulose or ribbed; shell outlets are wide and shallow, aperture narrow, and both lips are denticulate.

Recent species of Eratoinae have been recorded from the Indo-Pacific, Europe, West Indies and the west coast of America. Tropical Eratoinae are reef-dwellers, and inhabit crevices of the underside of coral blocks.

*Lachryma* SOWERBY [1832]

- Lachryma* SOWERBY, [1832], Conch. Illust., Cat. Cyp., p. 15. Type species by T *Erato lachryma* SOWERBY, 1832  
 [1832]. [*Erato*] *lachryma* GRAY, SOWERBY. *Lachryma trifasciata* HUMPHREY, Mss. Conch. Illust., fig. 48  
 1927. *Proterato* SCHILDER, Arch. Naturgesch., 91A: 57 (Type species by OD *Erato neozelanica* SUTER, 1917)  
 1931. *Lachryma* IREDALE, Rec. Aust. Mus., 18: 223 (in combination *Lachryma bisinventa* IREDALE, 1931)  
 1935. *Lachryma* SOWERBY, IREDALE, Aust. Zool., 8: 97  
 1935. *Eratoena* IREDALE, Aust. Zool., 8: 97 (Type species by OD *Ovulum corrugatum* HINDS, 1845 = *Erato sulcifera* SOWERBY, 1832)  
 1958. *Lachryma* SOWERBY, COTTON, Journ. Malacol. Soc. Aust., No. 2: 11

Shells are very small, biconical, smooth or granulose, spire broad and often projecting, dorsal groove prominent or obsolete, aperture narrow, lips denticulate, posterior columellar denticles occasionally obsolete.

**Discussion:** *Lachryma* SOWERBY [1832] will have to replace *Proterato* SCHILDER, 1927. *Lachryma* was published by SOWERBY [1832] in the synonymy of *Erato lachryma* SOWERBY, 1832, ex HUMPHREY MS. *Lachryma* has been treated as an available name with its original date and authorship prior to 1961 (art. 11d, Code of ICZN, 1964) and has been adopted as the name of a taxon by IREDALE (1935) and COTTON (1958).

The date of publication of the "Catalogue of Cypraeadae" by SOWERBY appears to be in dispute. SCHILDER (1933) quotes 1837 as the publication date, whereas IREDALE cites the 16<sup>th</sup> November 1832. SHAW (1909a) seems to favour the latter date, as a part of the "Catalogue of Cypraeadae" (? pp. 1-8) has definitely been issued with part 7 of the Conchological Illustrations (9 November 1832). The remaining pages 9-18 probably appeared with part 8 (prior to 30 November 1832). Malacologists not accepting 1832 as the publication date would have to date *Lachryma* from 1837, the date of

appearance of the "Index to the Cypraeadae" with part 131 (15 November 1837).

IREDALE (1935) established *Eratoena* for Recent tropical species of Eratoinae with sculptured shells; he pointed out that although the sculpture can become "sub-obsolete," the species can be distinguished by apertural characters, which he did not specify. When IREDALE mentioned apertural differences between *Lachryma* and *Eratoena*, he probably meant the difference in denticulation of the columellar lip. In *Lachryma lachryma* (SOWERBY) the posterior columellar denticles are obsolete, but they can be prominent along the whole length of the columella in *Lachryma sulcifera* (SOWERBY) or can be obsolete posteriorly. This feature is rather variable, and SCHILDER (1933) states that specimens of *L. callosa* (ADAMS & REEVE, 1848) with obsolete or prominent posterior columellar teeth are represented in about equal numbers. Since *Eratoena* has been based on variable specific characters, it is relegated to the synonymy of *Lachryma* SOWERBY, following SCHILDER (1939, but not 1941).

*Proterato* SCHILDER could questionably be retained as a subgenus of *Lachryma* for the New Zealand Miocene fossil *Erato neozelanica* SUTER, 1917, which is rather globular, smooth, with a conical spire, obsolete posterior columellar teeth, and has a somewhat wider aperture.

*Lachryma sulcifera* (SOWERBY, 1832)

(Plate 52, Figures 22, 22 a)

1832. *Erato sulcifera* SOWERBY, Conch. Illust., Cat. Cyp., p. 15; fig. 46  
 1845. *Ovulum corrugatum* HINDS, Zool. Voy. Sulphur, p. 47; plt. 16, figs. 5, 6  
 1859. ? *Erato nana* SOWERBY, Thes. Conch., 3: 82; plt. 219, figs. 12, 18  
 1867. *Erato schmeltziana* CROSSE, Journ. Conch., 15: 301; plt. 11, fig. 5 (Fiji Islands)  
 1933. *Proterato (Proterato) sulcifera capensis* SCHILDER, Proc. Malacol. Soc. London, 20: 248; fig. 22  
 1933. *Proterato (Proterato) sulcifera smithi* SCHILDER, Proc. Malacol. Soc. London, 20: 248; fig. 24  
 1933. *Erato (Cypraeerato) schneideri* SCHILDER, Zool. Anz., 102: 294, 296  
 1933. *Erato schmeltziana* (sic) CROSSE, DAUTZENBERG & BOUGE, Journ. de Conchyl., 77: 294

**Shell:** Marginellid in shape, spire elevated, apcx blunt, labial lip moderately broad, roundly angulate near shoulder; greenish or light greenish-fawn in colour, rarely greenish-white, occasionally banded with 1-3 bright green or greenish-brown transverse bands which may be broken up into blotches. Anterior extremity pinkish-brown or orange-brown. Sculptured with a deep or shallow

dorsal groove, numerous small granules which may coalesce into short or long axial riblets; some specimens are smooth and only granulose at the shoulder and spire. Labial lip with 15-21 denticles, which are either short or produced to the margin; columellar terminal ridge is transversely striate, columellar teeth are small denticles which may become obsolete posteriorly, and number from 8 to 18. Aperture is narrow, fossula either narrow or broad.

**Animal:** Foot long and slender, pointed posteriorly, cream in colour, finely spotted with brown at the margins. Mantle creamy-yellow, spotted with small brown spots and a few irregular and large brown zones. Siphon open, creamy-yellow, minutely spotted with brown; tentacles moderately long, slender, translucent creamy-white, finely spotted with brown; eyes black.

L: 2.8-4.3 mm; W: 61-68%

**Type Locality:** Cape of Good Hope.

**Habitat:** Under coral rocks, in shallow water.

Uncommon.

**Distribution:** Throughout the Fiji Islands. — From the Red Sea through the tropical Indo-Pacific to the Tuamotu Archipelago.

**Discussion:** Tropical species of Eratoinae are highly variable in colour and sculpture; what may be considered a specific diagnostic character may well be only an ecophenotypic variation. BARNARD (1963) observed that specimens of *Lachryma sulcifera* from South Africa are either smooth, granulose, axially ribbed or granulose only posteriorly, that the dorsal sulcus may be short or even absent and that the colour is variable. A similar variation has been observed in Fiji specimens. SCHILDER (1933) considers *L. corrugata* (HINDS) as a race of *L. sulcifera*, but admits that intermediate shells have been recorded and that in some localities both races seem to live together. This certainly holds true for Fiji, where the *corrugata* form lives side by side with typical *L. sulcifera*.

The difficulty of interpretation of diagnostic characters of Eratoinae is best documented by the taxon *Lachryma sulcifera schneideri* (SCHILDER) which was originally described as a full species in the genus *Erato* RISSO, 1826, subgenus *Cypraeerato* SCHILDER, 1932. It was reduced to the rank of a subspecies the same year and transferred to *Proterato* s. str. In 1941 *Lachryma schneideri* was once again considered to be a good species and was assigned to the subgenus *Sulcerato* FINLAY, 1930, while *Lachryma sulcifera* was transferred to the subgenus *Eratoena* IREDALE, 1935. The majority of geographical races of *Lachryma sulcifera* have been based on diagnostic characters (c.g. absent dorsal groove, granules becoming riblets, granules confined to spire or base), which can be observed

in populations of *L. sulcifera* from a confined geographical region.

## UNCONFIRMED REPORTS

### *Primovula (Diminovula) margarita* (SOWERBY, 1828)

(Plate 52, Figures 23, 24, 25)

1828. *Ovulum margarita* SOWERBY, Zool. Journ., 4: 150

1828. *Licium margarita* SOWERBY (ex HUMPHREY MS), Zool. Journ., 4: 150, in synonymy of *Ovulum margarita* SOWERBY, 1828)

1830. *Ovulum margarita* SOWERBY, Spec. Conch., *Ovulum*, 1: 4; figs. 19, 20

1849. *Ovulum umbilicatum* SOWERBY, Proc. Zool. Soc. London, 16: 135

One very worn specimen collected in the Fiji Islands could possibly be this species, but since it is partially broken, the identification is not at all certain.

**Type Locality:** In Insulis quas "Friendly" vocamus, in Mari Pacifico [= Tonga Islands].

**Dimensions of type series:**

L: 8.2 - 13.8 mm; W: 65 - 70%; LT: 22 - 29; crenulations on first funiculum: 3 - 6.

**Discussion:** SOWERBY (1828) described the species from several specimens in the Humphrey collection and remarked that all specimens bar one were pierced and strung by natives. The type series of *Ovulum margarita* preserved in the British Museum (Natural History) consists of 5 specimens; 4 of these have been holed above the labial margin, and the smallest specimen is complete (N. Tebble, *in litt.*). SOWERBY's dimensions of the holotype given in the original publication were length 11/20 poll. (= 13.97 mm) and width 4/10 poll. (= 10.16 mm); these dimensions closely correspond with the holotype, which is the largest specimen in the series. The dimensions of the type series of *O. margarita* are as follows:

**Holotype:** B. M. N. H. Reg. No. 1967613/1. L: 13.8 mm; W: 9.5 mm; LT: ca. 29; first funiculum with ca. 3 crenulations.

**Paratype:** B. M. N. H. Reg. No. 1967613/2. L: 8.2 mm; W: 5.5 mm; LT: ca. 28; (the only complete specimen, slightly immature).

**Paratype:** B. M. N. H. Reg. No. 1967613/3. L: 12.1 mm; W: 8.5 mm; LT: ca. 23; first funiculum with ca. 6 crenulations.

**Paratype:** B. M. N. H. Reg. No. 1967613/4. L: 8.8 mm; W: 6.2 mm; LT: ca. 22; first funiculum with ca. 4 crenulations.

**Paratype:** B. M. N. H. Reg. No. 1967613/5. L: 11.5 mm; W: 7.5 mm; LT: ca. 24; first funiculum with ca. 3 crenulations.

The species is pyriform, inflated and generally white in colour; the dorsum is finely transversely striate, and a dorsal carina is either absent or feebly pronounced. Labial teeth are strong but irregular, the first funiculum is prominent and crenulate, the posterior outlet is distinct, posterior extremity calloused and recurved and the fossula is concave.

WEINKAUFF (1881) also reported this species from the Tonga Islands, and SCHILDER (1941) lists the distribution for this species as ranging from Indonesia to the Philippines, Bismarck Archipelago and the Tonga Islands.

## FOSSIL RECORDS

### *Trivirostra (Trivirostra) koroensis* (LADD, 1934)

1934. *Trivia (Trivia) koroensis* LADD, Bernice P. Bishop Mus. Bull., 119: 220; pl. 39, figs. 9, 10

The species was described from late Tertiary (Pliocene) deposits at station 160 (Walu Bay, Suva, few feet above sea-level). The length was given as 3.9 - 4.7 mm, the width (calculated) as 68 - 69% of length, and the height as 62% of length. The holotype of *Trivirostra koroensis* has 27 labial and 23 columellar teeth and ca. 32 - 34 dorsal ribs (counted from type figure).

The species resembles *Trivirostra hordacea* (KIENER, 1843), but has somewhat more numerous teeth on both lips.

## SUMMARY

Further records of species of the 3 families treated in this monograph are only to be expected. In the case of rare species only diligent collecting over a great number of years can present a true record of the actual existence of species of any molluscan family in a certain geographical region.

The total number of species recorded in the various genera of the 3 families is as follows:

## OVULIDAE

<i>Ovula</i>	2
<i>Calpurnus</i>	2
<i>Prosimnia</i>	1
<i>Primovula</i>	2
<i>Prionovolva</i>	1
<i>Volva</i>	1
<i>Phenacovolva</i>	3
<i>Pseudocypraea</i>	1
Total	13

## PEDICULARIIDAE

<i>Pedicularia</i>	1
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## TRIVIIDAE

<i>Trivirostra</i>	7
<i>Lachryma</i>	1
Total	8

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# *Aplysia vaccaria*, a New Host for the Pinnotherid Crab

## *Opisthopus transversus*

BY

ANTHON CRAIG BEONDÉ

Department of Biology

California State College at Long Beach, Long Beach, California 90804

(2 Text figures)

ON APRIL 2, 1967, TWO SPECIMENS of *Aplysia vaccaria* WINKLER, 1955, were collected at Corona del Mar State Beach, California, for anatomical studies. From each *A. vaccaria* a specimen of the pinnotherid crab *Opisthopus transversus* RATHBUN, 1893, was obtained. Both sexes were obtained. The carapace widths were 10.4 mm and 10.5 mm for the male and female respectively. Further collecting at Corona del Mar State Beach, and examination of 15 *A. vaccaria* and 29 *A. californica* COOPER, 1863, did not yield any additional specimens.

The two specimens of *Opisthopus transversus* were originally observed leaving the pallial cavities of *Aplysia vaccaria* while the mollusks were being prepared for dissection. Their significance was not realized at the time and no observations were made on any possible damage they may have done to the pallial cavity or ctenidium.

PEARCE (1966) observed extensive ctenidial erosion in *Mytilus edulis* LINNAEUS, 1758, associated with the pinnotherid crab *Fabia subquadrata* DANA, 1851. MACGINITIE & MACGINITIE (1949) and PEARCE (1966) both observed that *Fabia* fed upon the food string produced by the ctenidia in *Mytilus* and that while feeding upon this string would occasionally eat sections of the ctenidium. McDERMOTT (1962) had made similar observations with *Pinnotheres ostreum* SAY, 1817, where he found that the ctenidial edge in *Anomia* showed swelling and perforation accompanied in some cases with polyp erosion.

Numerous hosts for *Opisthopus transversus* have been recorded, although it is seldom mentioned in the literature and rarely encountered. Table 1 gives the recorded hosts along with the respective references.

What may prove to be of more interest is the great number of hosts with which *Opisthopus transversus* has been associated, but that it also chooses to live with *Aplysia*, an animal that to date has no recorded commensal associations, or predators, except possibly *Anthopleura*

(WINKLER & TILTON, 1962). It was not until 1962 that VICENTE described the first known parasite from *Aplysia*: a trematode metacercaria parasitic upon the nerve ganglia.

In its pelecypod hosts, *Opisthopus transversus* remains

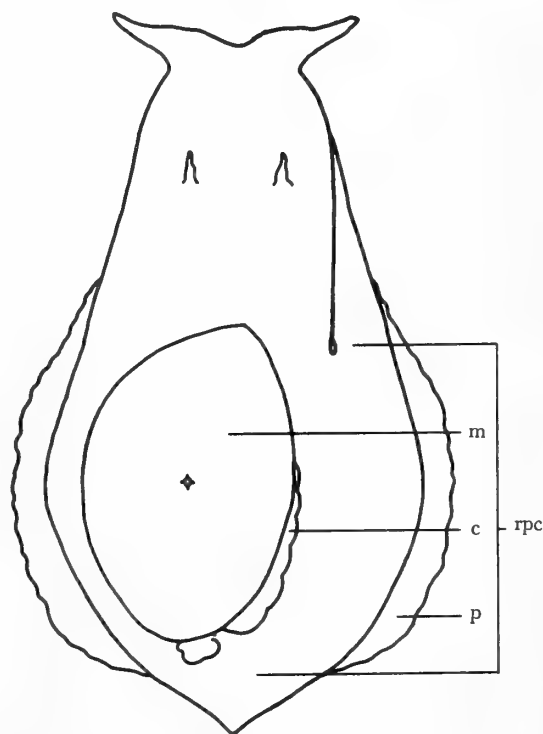


Figure 1

Dorsal View of *Aplysia vaccaria*  
 C - Ctenidium    M - Mantle    P - Parapodium  
 RPC - Right Pallial Cavity

Table 1

Recorded Hosts for the Pinnotherid Crab *Opisthopus transversus* and the Respective Literature References.

Mollusca	
<b>AMPHINEURA</b>	
<i>Amicula stelleri</i> (MIDDENDORFF, 1847) (= <i>Cryptochiton stelleri</i> )	RICKETTS & CALVIN, 1939; MACGINITIE & MACGINITIE, 1949
<b>GASTROPODA</b>	
<i>Megathura crenulata</i> (SOWERBY, 1835)	RATHBUN, 1893; 1904; 1918; WEYMOUTH, 1910; SCHMITT, 1921; RICKETTS & CALVIN, 1939; MACGINITIE & MACGINITIE, 1949
<i>Astraea undosa</i> (WOOD, 1828)	SCHMITT, 1921 <sup>1</sup>
<i>Polinices lewisii</i> (GOULD, 1847)	MACGINITIE & MACGINITIE, 1949
<i>Navanax inermis</i> (COOPER, 1862)	MACGINITIE & MACGINITIE, 1949
<i>Bulla gouldiana</i> PILSBRY, 1895	RICKETTS & CALVIN, 1939; MACGINITIE & MACGINITIE, 1949
<i>Aplysia vaccaria</i> WINKLER, 1955	
<b>PELECYPODA</b>	
<i>Mytilus edulis</i> LINNAEUS, 1758	RATHBUN, 1904; 1918; SCHMITT, 1921
<i>Pholas</i> sp.	RATHBUN, 1904; 1918; RICKETTS & CALVIN, 1939
<i>Sanguinolaria nuttallii</i> CONRAD, 1837	MACGINITIE, 1935; MACGINITIE & MACGINITIE, 1949
<i>Schizothaerus nuttallii</i> (CONRAD, 1837) (= <i>Tresus nuttallii</i> CONRAD, 1837)	SCHMITT, 1921 <sup>1</sup> ; RICKETTS & CALVIN, 1939; MACGINITIE & MACGINITIE, 1949
<i>Zirfaea</i> sp.	MACGINITIE & MACGINITIE, 1949
<i>Platyodon</i> sp.	MACGINITIE & MACGINITIE, 1949
<i>Modiolus</i> sp.	MACGINITIE & MACGINITIE, 1949
<i>Megapitaria squalida</i> (SOWERBY, 1835)	GARTH, 1967 <sup>2</sup>
Echinodermata	
<b>HOLOTHUROIDEA</b>	
<i>Stichopus californicus</i> (STIMPSON, 1857)	WEYMOUTH, 1910; RATHBUN, 1918; SCHMITT, 1921, RICKETTS & CALVIN, 1939; MACGINITIE & MACGINITIE, 1949

<sup>1</sup> SCHMITT (1921) notes that Mr. E. P. Chace of Los Angeles collected specimens with *Astraea undosa* and *Schizothaerus nuttallii*.

<sup>2</sup> Dr. Garth in a personal communication (1967) mentions that only two specimens are in the Allan Hancock collection. One found with *Megapitaria squalida*, was collected at Laguna San Ignacio, Baja California, by Mr. R. L. Eberhart of the California Department of Fish and Game. The other was collected with *Megathura crenulata* at Santa Monica, California.

safe within the confines of, and relies upon the host to collect its food. However, with the gastropod, amphineuran, and holothuroidean hosts it becomes evident that *O. transversus* is forced occasionally to leave the protected confines and forage for food. *Aplysia* does not offer the advantage of being a ctenidial feeder: the ctenidium serves purely a respiratory function.

Figure 1 represents a dorsal view of the pallial cavity of *Aplysia vaccaria* and depicts the large area between the mantle shelf on the left and the overhanging parapodial flap on the right, an area in which the crabs could

freely move. *Aplysia vaccaria*, unlike *Aplysia californica*, usually keeps the parapodial flaps closed over the pallial cavity. The parapodia in *A. vaccaria* are thick and muscular while those in *A. californica* are thin and fleshy, which, when the animal is active, hang loosely out into the water, thereby exposing the pallial cavity. Figure 2 depicts what remains of the "left" pallial cavity that would have ancestrally contained the left ctenidium. This is a small cavity found beneath the overhanging mantle with its enclosed shell. There is a small aperture to the pallial cavity at the base of the ctenidium. In a specimen

of *A. vaccaria*, 10 inches long, this cavity is large enough to allow entrance of the index finger with ample room to spare. Since this area is well shut off from the outside and protected by the shell overhead it would be the most likely place to find *Opisthopus transversus*.

Generally pinnotherid crabs display host specificity, but there are recorded instances where more than one host may be utilized, or where more than one host may be involved in the life cycle of a single species. McDERMOTT (1962, in reviewing CHRISTENSEN, 1958: On the life history and biology of *Pinnotheres pisum*) has reported that *Pinnotheres pisum*, a European species, may utilize two mollusks in completing its life history. He also referred to *P. ostreum*, a species commonly found in the pelecypod *Anomia*. It is evident that *P. ostreum* first invades *Mytilus* in the fall, where it seeks shelter, and matures to the hard stage in winter at which time it is no longer found. Both sexes possibly leave the hosts and seek other mollusks (i. e. *Anomia*) in which the female may grow to maturity. This may partially explain the recorded hosts for *Opisthopus transversus* or it may be simply that *O. transversus* has only recently evolved a commensal relationship and

of a food supply, and 3. the protection afforded by the host animal.

*Opisthopus transversus* is known to range as far north as Monterey, California (RATHBUN, 1904) and as far south as San Felipe, Baja California (GLASSELL, 1935). NININGER (1918) reported having dredged specimens from a depth as great as 40 metres off Laguna Beach, California. *Aplysia vaccaria* ranges from Morro Bay, California, to Bahía de Los Angeles, Baja California (LANCE, 1967), totally within the known range of *O. transversus*.

### ACKNOWLEDGMENT

The writer is indebted to Mr. Roby Ward Renshaw, California State College at Long Beach, for his invaluable assistance in preparing and proof reading this paper.

Addendum at time of proof-reading:

The following additions to Table 1, due to the original oversight of

HOPKINS, THOMAS S. & THOMAS B. SCANLAND

1964. Host relations of a pinnotherid crab *Opisthopus transversus* RATHBUN. Bull. So. Calif. Acad. Sci. 63: 175 - 180 should be made:

*Opisthopus transversus* was found commensally with 4 known hosts: *Megathura crenulata*, *Astraca undosa*, *Bulla gouldiana*, and *Schizothaerus nuttallii* [= *Tresus nuttallii*] - and 6 new hosts: the polychaete *Chaetopterus variopedatus* (RENIER, 1804), the mollusks *Zirfaea pilsbryi* LOWE, 1931, *Hinnites multirugosus* (GALE, 1928), *Trachycardium robustum* and the holothurians *Parastichopus parvimensis* (CLARK, 1913), and *Molpadia arenicola* (STIMPSON, 1857).

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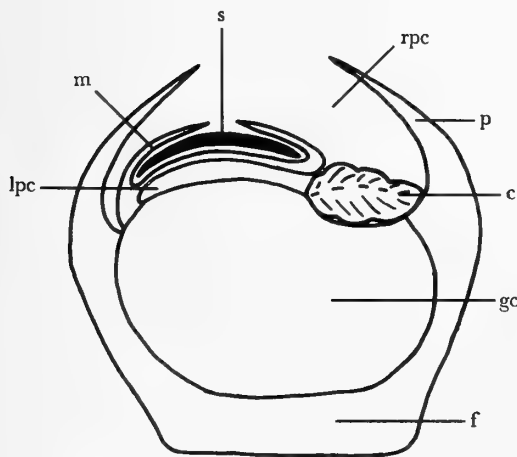


Figure 2

Cross-Sectional View of *Aplysia vaccaria*

G - Ctenidium      F - Foot      GC - Gut Cavity  
LPC - "Left" Pallial Cavity      M - Mantle      P - Parapodium  
RPC - Right Pallial Cavity      S - Shell

is presently experimenting with many possible hosts. The choice of a host may therefore be dependent upon three simple factors: 1. the size of the crab itself, 2. the host's ability to supply or bring it within close proximity

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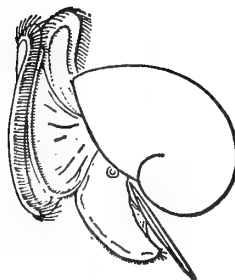
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# Taxonomic Placement of *Coralliophila incompta* BERRY, 1960, With the Proposal of a New Genus, *Attiliosa*

(Gastropoda : Muricacea)

BY

WILLIAM K. EMERSON

Department of Living Invertebrates, American Museum of Natural History  
Seventy-ninth Street and Central Park West, New York, New York 10024

(Plate 53; 5 Text figures)

DURING THE PROCESS of sorting the mollusks obtained by the Puritan-American Museum Expedition to western Mexico of 1957, two specimens of an apparently new species of stenoglossid gastropod were found in a dredge sample from off Isla Angel de la Guarda. The conchological and opercular characters of these specimens suggested to us at the time taxonomic placement near the genus *Cantharus*, in the Buccinidae. These specimens, along with other unidentified material from this vast collection, were set aside for future study. Shortly thereafter, *Coralliophila incompta* was described by BERRY (1960) from specimens that also were dredged off Isla Angel de la Guarda, in the Gulf of California. The Puritan specimens, together with additional specimens in our collection taken by Mexican fishermen operating out of Guaymas, Sonora, are conspecific with BERRY's taxon for which only an abbreviated diagnosis, lacking an illustration, has been published. The holotype of BERRY's taxon is figured herein, courtesy of Dr. James H. McLean.

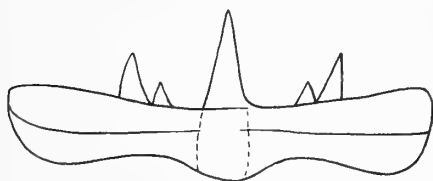


Figure 1

Radular rachidian tooth of *Cronia amygdala* (KIENER), type species of *Cronia* H. & A. ADAMS; greatly enlarged, dorsal view, after COOKE (1919, fig. 33).

My colleague, Anthony D'Attilio, who is an ardent student of the Magilidae, recently expressed his opinion that BERRY's *incompta* was not referable to the genus *Coralliophila*. Mr. D'Attilio submitted three live-taken specimens to Mr. Masao Azuma of Nishinomiya, Japan, who kindly provided us with a description and drawing of the radulae that he extracted from the specimens. Inasmuch as the shell of *incompta* is not characteristic of *Coralliophila* and a radula is not known to occur in the Magilidae [Coralliophilidae], the placement of BER-

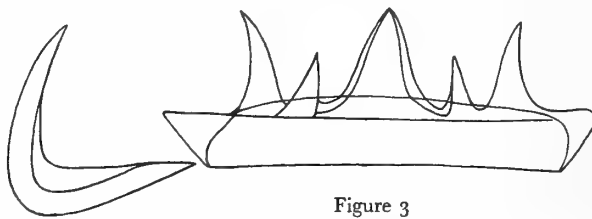


Figure 2

Figure 3

Figures 2, 3

Radular teeth of *Attiliosa incompta* (BERRY), type species of *Attiliosa*, new genus; greatly enlarged, dorsal view.

Figure 2: Lateral tooth. Figure 3: Rachidian tooth  
(Drawings courtesy of Mr. Azuma)

RY's taxon in that family would appear to be untenable. The radula was found to be similar to those possessed by species in the genus *Cronia* H. & A. ADAMS (1853) of the muricacid subfamily Thaisinae (see Text Figures 2 and 3). The type species of *Cronia* is *Purpura amygdala* KIENER (1836), by monotypy (see Text Figure 1).

The placement of "*Coralliophila*" *incompta* BERRY in the subfamily Thaisinae near the genus *Cronia*, necessitates the proposal of a new generic name:

*Attiliosa* EMERSON, new genus

**Diagnosis:** A thaisinid with a semi-ovate shell of moderate size; spire acuminate; aperture large with spiral lirations within the outer lip, and with small lirations anteriorly placed on the inner lip; anterior canal relatively long; base with siphonal fasciole. Radula with 3 major and 2 lesser cusps on central teeth (Text Figure 3). Operculum "purpuroid," *i. e.* with a lateral nucleus and a prominent marginal inner callus (Text Figures 4 and 5).

**Type Species:** *Attiliosa incompta* (BERRY, 1960).

**Remarks:** The type species of *Attiliosa* is characterized by the possession of prominent lirations within the aperture on the outer lip, by the development of a broad siphonal fasciole, and by having an extended, somewhat recurved siphonal canal.

It is my pleasure to name this new taxon in honor of my valued friend, Mr. Anthony D'Attilio.

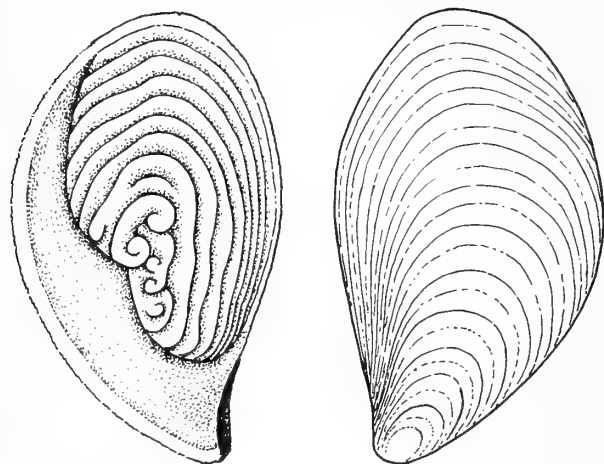


Figure 4

Figure 5

Figures 4, 5

Operculum of *Attiliosa incompta* (BERRY); greatly enlarged.  
Figure 4: Inner surface. Figure 5: Outer surface.

*Attiliosa incompta* (BERRY, 1960)

(Plate 53, Figures 1 - 5; Text Figures 2 - 5)

*Coralliophila incompta* BERRY, 1960, pp. 119 - 120; type locality: "20 mi. off Puerto Refugio, Isla Angel de la Guarda, Baja California," Mexico; B. W. Walker, 20 to 21 Apr. 1953; holotype here illustrated, Plate 53, Figure 1. DuSHANE & POORMAN, 1967, p. 429, Guaymas, Sonora, Mexico, dredged in 10 - 45 fathoms, on rock and gravel bottom.

**Additional Records:** Off southeast end of Isla Angel de la Guarda, Mexico, 29° 01' 00" N, 113° 07' 00" W, dredged in 15 - 17 fathoms, on sand? bottom, 1 live-taken specimen, May 20, 1957 (Puritan expedition, station 167; EMERSON, 1958), A. M. N. H. No. 77128.

Off southeast end of Angel de la Guarda Island, Mexico, 29° 01' 30" N, 113° 07' 20" W, dredged in 16 to 17 fathoms, on sand?, 1 live-taken specimen, May 20, 1957 (Puritan expedition station 168; EMERSON, 1958), A. M. N. H. No. 77143.

Gulf of California, Mexico, trawled by fishermen, cruising out of Guaymas, Sonora, 6 live-taken specimens, ex. Purdy collection, A. M. N. H. No. 138277; 4 specimens, Germer collection.

Holotype deposited in Stanford University Paleontology Type Collection No. 9512; *ex* collection of S. S. Berry, No. 18768.

## ACKNOWLEDGMENTS

In addition to Messrs. Azuma and D'Attilio, I am greatly indebted to the following individuals for courtesies of various kinds: Mrs. Helen DuShane of Whittier, California, Mrs. John Germer of Maywood, New Jersey, Dr. James H. McLean of the Los Angeles County Museum of Natural History, Mr. and Mrs. Ben Purdy of San Diego, California, and Mr. William E. Old, Jr. of the American Museum of Natural History.

Mr. A. A. Olsson of Coral Gables, Florida kindly read the manuscript.

## Explanation of Plate 53

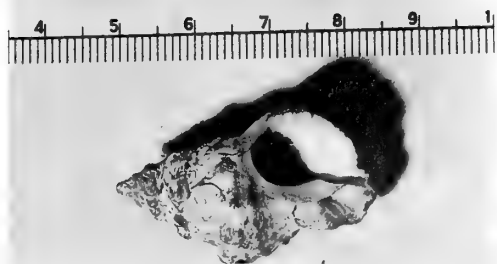
*Attiliosa incompta* (BERRY, 1960)

Figure 1: Holotype (x 1)

Figure 2: Mature specimen from Puritan Station 167 (American Museum of Natural History No. 77128); (x 2)

Figure 3: Juvenile specimen, with immature lip, Gulf of California (American Museum of Natural History No. 138277); (x 2)

Figures 4, 5: Mature specimen from Puritan Station 168 (American Museum of Natural History No. 77143); (x 2). Note prominent siphonal fasciole and lirations extending within the aperture in Figure 4. Exterior of shell largely covered with foreign matter in Figure 5.



No. 9512 ..... Holotype  
*Coralliophila incompta* .....  
 ..... Berry .....  
 Formation ..... Age. Recent .....  
 Locality Off Puerto Refugio 20 mi  
 Angel de la Guarda I., Gulf of  
 California  
 Stanford Univ. Paleo. Type Coll.

Figure 1



Figure 2

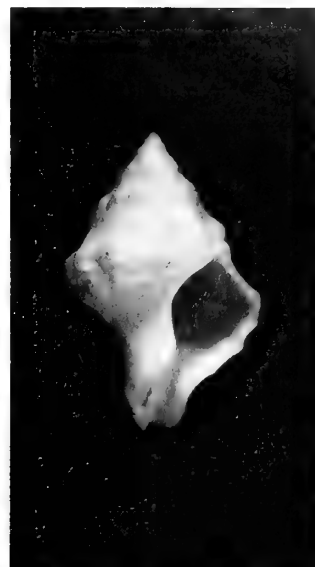


Figure 3



Figure 4



Figure 5



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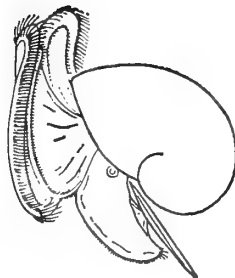
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## A New Cowrie Species from the Philippines

BY

CRAWFORD N. CATE

12719 San Vicente Boulevard, Los Angeles, California 90049

AND

FRANZ ALFRED SCHILDER

University of Halle, German Democratic Republic

(Plate 54)

DURING AUGUST 1967, Mr. Fernando G. Dayrit, University of the Philippines Village, Diliman, Rizal, Philippines, received a curious small cowrie which had been collected alive off Laminusa Island, Siasi Group, in the south-western Philippines (see CATE, 1966; map, p. 237). The small, slender shell superficially recalls *Notadusta rabaulensis* SCHILDER, 1964, but some of its shell characters, especially the reduced fossula and the dorsal blotch, prove it to be related to *Erronea pallida* (GRAY, 1824) and more particularly to its south-eastern race *E. p. insulicola* SCHILDER & SCHILDER, 1938. The differences, however, are so striking that we think the shell belongs to a distinct species that is new to science; we propose to call it:

*Erronea stohleri* CATE & SCHILDER, spec. nov.

**Holotype:** The unique holotype of *Erronea stohleri* is 15.1 mm long, 8.2 mm broad, and 6.9 mm high, and shows 18 labial and 17 columellar teeth (the two terminal ridges excluded, but a small intercalated columellar tooth included); therefore the characters, as tabulated by M. SCHILDER (1967, p. 373) read for this species as follows: 15/54, 18:17, *ps.*

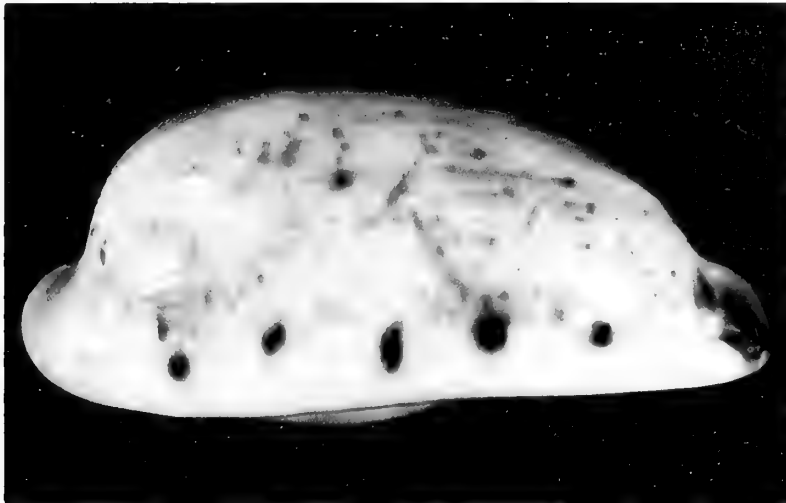
The adult shell is elongate pyriform, only slightly callos, with the spire projecting from a shallow umbilicus; the equally narrow right margin is separated by a rather indistinct dorsal rim, the left margin is regularly convex; the terminal impressions are distinct in front, but obsolete behind; the base is rather flattened, impressed in front, inner lip slightly convex behind with its posterior beak acuminate and bent to the left; the aperture is narrow, distinctly widened in front and distinctly bent behind; the labial teeth are short even in the declivous anterior ex-

tremity; the terminal tooth is composed of 2 long, slender convergent ridges the anterior of which borders the outlet; it is well separated from the columellar teeth, the anterior of which are much coarser than the short central ones and the rather oblique posterior ones (the last tooth lies on the base of the posterior beak the inner margin of which is smooth); the fossula is much reduced, as the three strong anterior columellar teeth project towards the aperture and cross the vertical plane plate as far as its inner margin, forming three continuous vertical ribs without any swelling interiorly; the columella shows no longitudinal sulcus, it is constricted in front and crossed here by vertical ribs similar to those of the fossular plate, but ventricose behind with traces of interior denticles terminating the obsolete transversal ribs.

Dorsum grey, without transversal zones, irregularly freckled with often confusely confluent fulvous-brown specks, and adorned with a large square fulvous-brown central blotch; margins and base whitish; outer margin with six small chestnut spots which do not extend to the base, left margin with four obsolete spots in front only; extremities suffused with pale greyish fulvous, anterior extremity with two blackish brown spots which are restricted to the dorsal area, posterior extremity practically unspotted; teeth white without any traces of colored striae; spire pale fulvous.

**Type Locality:** The animal was collected alive in approximately two fathoms of water off Laminusa Island.

**Type Repository:** The holotype is deposited in the California Academy of Sciences Geology Department Type collection, where it bears the number 13101. The holotype is figured on Plate 54.



*Erronea stohleri* CATE & SCHILDER  
Lateral, dorsal and ventral views of the holotype



**Discussion:** Size and shape of the holotype of *Erronea stohleri* recall to mind *Notadusta rabaulensis* SCHILDER, 1964, fig. 1; see also 1966, figs. 1-3), but *E. stohleri* differs from it by the coarser anterior columellar teeth which cross the narrow vertical fossula without any impression instead of being compressed in the central part along the fossula and thickened within as a row of inner denticles. Besides, in *E. stohleri* the dorsum is not zonate, it shows irregularly confluent specks instead of regularly distributed round spots, and a large central blotch never observed in any species of *Notadusta*; the scarce lateral spots do not extend to the base, and the teeth of both lips are far less numerous.

These and other characters agree with *Erronea pallida insulicola* SCHILDER & SCHILDER (1938, p. 148); however, *E. stohleri* is much smaller, more elongate, less callous so that the right margin is vertical and the base flattened, with the hind top of the inner lip more acute, and with finer and more numerous teeth; the features of the fossula agree with those of *E. p. insulicola*, whereas in typical *E. p. pallida* (GRAY, 1824) the anterior columellar teeth project far more so that they become rather semicircular within, not reaching the inner border of the fossular plate.

There is a remarkable parallelism of the morphological characters in relation to the geographical distribution: The central *Erronea pallida insulicola*, which lives on the north coast of Java, seems to be intermediate morphologically between the eastern, small, delicate *E. stohleri* from the Sulu Sea (southern Philippines), and the west-

ern callous *E. p. pallida*, which is distributed from the Gulf of Thailand via Singapore and Burma to India and the Persian Gulf. The common ancestor, *E. vredenburgi* SCHILDER (1927) with a distinctly concave real fossula is restricted to the south coast of Java from the Sunda Strait to Bali.

This species is named in honor of Dr. Rudolf Stohler of the University of California, Berkeley, California, in recognition of his tireless efforts in promoting Malacology, as the author of many valuable papers on mollusca and as the founder and editor of "The Veliger."

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Studies on the *Mytilus edulis* Community  
in Alamitos Bay, California  
III. The Effects of  
Reduced Dissolved Oxygen and Chlorinity Concentrations  
on Survival and Byssus Thread Formation

BY

DONALD J. REISH

AND

JOSEPH L. AYERS, Jr.

Department of Biology  
California State College at Long Beach, Long Beach, California 90804

(2 Text figures)

DURING THE COURSE of studying the ecology of the *Mytilus edulis* LINNAEUS, 1758, community in Alamitos Bay, California (REISH, 1963, 1964a, 1964b) the senior author was interested in learning what biological or physical factors would limit or destroy the population. No animal was or has subsequently been observed to prey on *M. edulis* in this area. EBLING *et al* (1964) reported that crabs fed upon *M. edulis* in the laboratory and in suspended sea cages in English waters. An occasional crab, *Hemigrapsus oregonensis* (DANA, 1851), has been taken from mussel beds in Alamitos Bay, but it is not known whether or not it will feed upon it. No empty *M. edulis* shells have been observed with circular holes present as a result of radular drilling by snails.

A mass mortality of *Mytilus edulis* and associated organisms occurred in Alamitos Bay in 1962 following an extensive red tide bloom of the dinoflagellate *Gonyaulax polyhedra* STEIN (REISH, 1963). It was not known if the mussels were killed directly by the accumulation of toxic material in the body or indirectly by the decrease of dissolved oxygen in the water.

The chlorinity of the sea water throughout the bay is that of normal sea water (19.2‰). Decreases in chlorin-

ity in Alamitos Bay occur only following rains as the result of run-off from the surrounding area (STONE & REISH, 1965); however, the chlorinity returns to normal levels rapidly. It is not known whether or not these reduced chlorinities in Alamitos Bay are lethal to *Mytilus edulis*.

Two additional causes of community destruction may be cited. Large clumps of *Mytilus edulis* on floating docks may be dislodged by their own weight or by heavy waves and fall to the bottom. Dead mussel shells have been taken in bottom samples beneath these docks, but, of course, the cause of death was unknown. People utilize mussels as fishing bait.

Of the different possible causes of destruction to the mussels discussed above, two lend themselves to laboratory experimentation: reduced chlorinities and dissolved oxygen concentrations. The initial purpose, therefore, of this investigation was to determine the lethal limits of these two environmental factors on *Mytilus edulis* under controlled laboratory conditions. During the course of conducting the preliminary experiments, it was discovered that the production of byssal threads, which were used for attachment to the flask, was related to varying con-

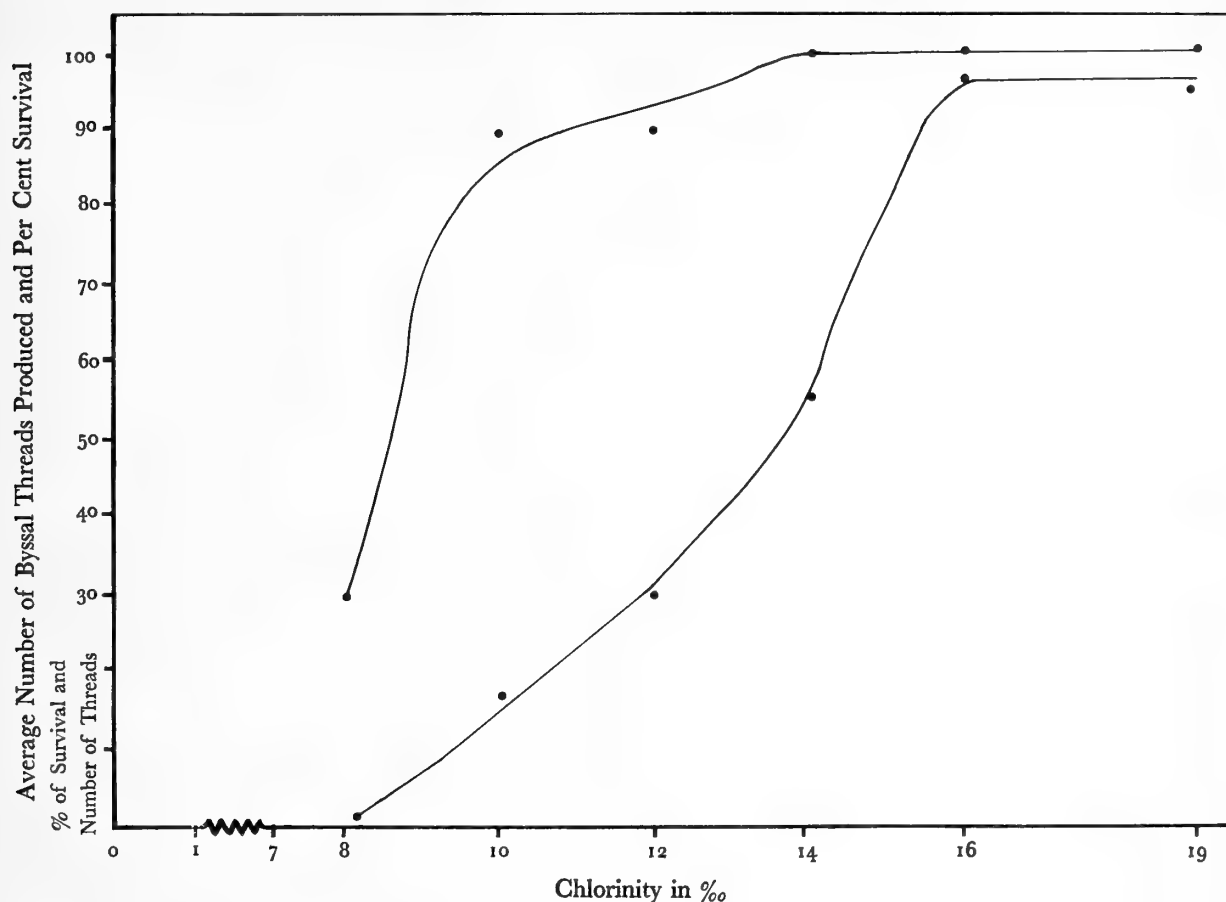


Figure 1

Survival and average number of byssal threads produced by *Mytilus edulis* under reduced concentrations of chlorinity during a 14 day period at 15°C to 16°C

centrations of chlorinity and dissolved oxygen. Therefore, it was possible not only to investigate the lethal concentrations of dissolved oxygen and chlorinity but also to ascertain intermediate levels of the condition of the animal by counting the number of byssal threads produced during the experimental period.

## MATERIALS AND METHODS

Specimens of *Mytilus edulis* were collected from the boat floats in Alamitos Bay marina. They were cleaned of fouling organisms from the surface of the shells and all their byssal threads were cut. Only specimens measuring from 15 to 20 mm in width were used. Preliminary studies indicated these smaller sized mussels produced a greater number of byssal threads per unit time than larger ones,

and since the gonads were immature, no spawning would occur during the course of the experiment. The specimens were then placed in aquaria in a cold bath with water temperatures of 15°C to 16°C. Specimens were left in the aquaria for 3 days. The specimens used in the experiments were cleaned again and the byssal threads cut. One specimen was placed in an Erlenmeyer flask with 150 ml of filtered sea water. Ten specimens were used for each concentration of dissolved oxygen and chlorinity. The animals were not fed during the course of the experiment.

Decreased chlorinities were made by adding an appropriate amount of distilled water. Chlorinities were determined by titrating with silver nitrate as outlined by BARNES (1959). The following chlorinity concentrations were used: 19.0 (control), 16.0, 14.0, 12.0, 10.0 and 8.0‰. The top was closed with a rubber stopper.

Decreased dissolved oxygen concentrations were obtained by flushing the overlying air in the Erlenmeyer flask with nitrogen gas through hypodermic needles which pass through the rubber stopper according to the procedure outlined by REISH & RICHARDS (1966). Three additional flasks, each with a mussel, were used for dissolved oxygen measurement during the course of the experiment. The dissolved oxygen concentration was determined with an electrode following the procedure described by REISH & RICHARDS (*op. cit.*). The dissolved oxygen values given in Figure 2 were determined by averaging the values measured within a series. These dissolved oxygen values were 4.5 (control), 2.1, 0.9, 0.6, 0.3, and 0.2 ppm.

The Erlenmeyer flasks containing the mussels were placed in the cold bath which maintained the temperature at 15°C to 16°C. Specimens were examined daily

for death and to count byssal threads. The byssal threads were attached along the sides of the flasks by the mussels.

Death was ascertained during the course of the experiment by noting the failure of the shell to close. When this condition occurred, the specimen was left another day as a check to see whether or not tissue decomposition had commenced. At the termination of the experiments, which ran for 14 days, the condition of the remaining specimens was determined.

## DATA

The data for the effects of reduced chlorinities on survival and byssal thread production are summarized in Figure 1. It can be seen from this figure that *Mytilus*

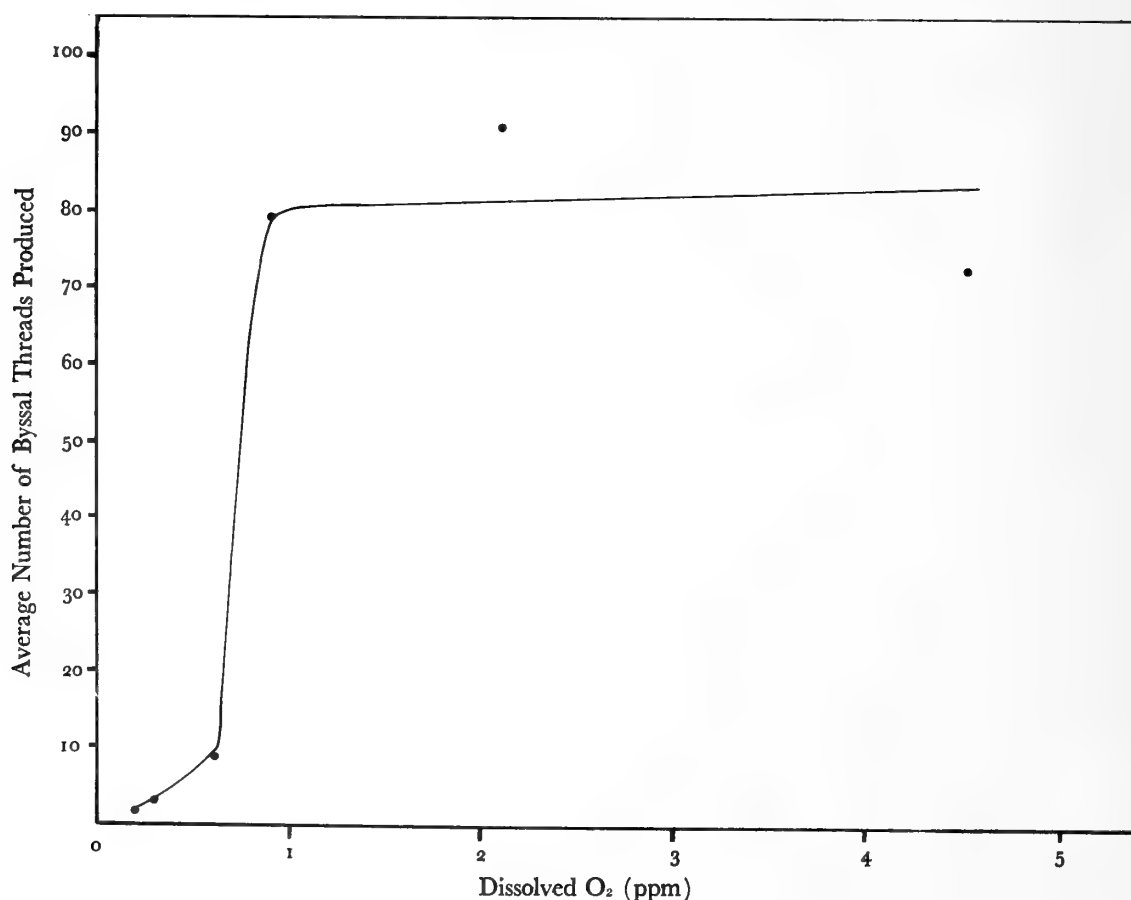


Figure 2

The average number of byssal threads produced by *Mytilus edulis* under reduced concentrations of dissolved oxygen during a 14 day period at 15°C to 16°C

*edulis* is capable of living for 14 days in chlorinities as low as 10.0‰. The 14 day median tolerance level ( $TL_m$ ) is approximately 8.6‰. However, these data are of interest when compared to the production of byssal threads during this 14 day period. The number of threads formed decreased at chlorinities between 14‰ and 16‰. The number of byssal threads continued to decrease to 10‰. No threads were secreted by these mussels at 8‰, but 30% of the specimens were still alive at the end of the 14 day period.

The relationship between the number of byssal threads produced and the dissolved oxygen concentration is given in Figure 2. Nearly all animals survived at all concentrations of dissolved oxygen. The difference between the number of threads produced at 0.9 ppm and 0.6 ppm is striking: 80 per animal per 14 day period as compared to 9.

## DISCUSSION

Small specimens of *Mytilus edulis* from Alamitos Bay are capable of surviving low concentrations of chlorinity and dissolved oxygen for a 14 day period at 15°C to 16°C under laboratory conditions. While the majority of the test organisms survived the reduced concentrations of chlorinity and dissolved oxygen, the specimens in the lower concentrations produced fewer byssal threads. The response of *M. edulis* in these lowered concentrations was similar; the two shells remained tightly closed most of the time. The shells of specimens in the controls of higher concentrations would be open.

Apparently *Mytilus edulis* is affected physiologically, as measured by byssal thread production, by chlorinities between 14‰ and 16‰, but is capable of surviving much lower levels. Chlorinities as low as 2.7‰ have been measured in Alamitos Bay (STONE & REISH, 1965). Since there are no rivers emptying into Alamitos Bay, recovery to normal chlorinities is rapid following the fresh water run-off from rain. If the rain falls over a week or more, which may occur some years, then the effects of this run-off could become an important survival factor to a population of *M. edulis*. It is of interest to note that populations of *M. edulis* occur in chlorinities of 8‰ in the Baltic Sea (SCHLIEPER, 1955).

The survival of *Mytilus edulis* in a reduced dissolved oxygen environment under laboratory conditions has not been studied previously. During a red tide bloom of the dinoflagellate *Gonyaulax polyhedra* in Alamitos Bay in 1962 (REISH, 1963), the dissolved oxygen content of the water was lowered as a result of the decomposition of dead protozoans and other organisms. Dissolved oxygen

concentrations as low as 0.1 ppm were measured, but it was unknown how long this low level persisted.

The relationship of byssal thread production in *Mytilus edulis* to altered environmental conditions has not been observed in the past. It seems logical to assume that the fewer number of threads secreted would reflect a lower metabolic rate. A reduced metabolic rate, as measured by oxygen consumption, was measured in mussels living in chlorinities below their range of tolerance (BOUXIN, as reviewed by KINNE, 1964). Similar decreases in metabolic rate employing other measures of activity, but with a similar experimental procedure, have been noted in polychaetes (REISH, 1966) and in the wood-boring isopods *Limnoria* (ANDERSON & REISH, 1967). Four species of polychaetes, *Nereis grubei* (KINBERG, 1866), *Dorvillea articulata* (HARTMAN, 1938), *Neanthes arenaceodentata* (MOORE, 1903), and *Capitella capitata* (FABRICIUS, 1780), failed to eat algae under sublethal concentrations of dissolved oxygen. Fecal pellet production in *Limnoria tripunctata* (MENZIES, 1951), *L. quadripunctata* (HOLTHUIS, 1949), and *L. lignorum* (RATHKE, 1799), was directly related to the dissolved oxygen concentration. The daily egestion rate decreased markedly in dissolved oxygen concentrations of less than 2.0 ppm.

It is apparent from these data that *Mytilus edulis* can withstand lowered chlorinities and dissolved oxygen concentrations for extended periods of time. The shells remain closed under these altered conditions. Correlating these data with field conditions, it is evident that if lowered environmental conditions extend for only a short period of time, then *M. edulis* would be able to withstand these conditions by keeping its shells closed. If, on the other hand, reduced dissolved oxygen concentrations or chlorinities extend over a longer period of time, such as a week or two or more, then the survival factor for *M. edulis* would become critical. Since some knowledge of the limiting values of dissolved oxygen and chlorinity on *M. edulis* are now known under laboratory conditions, it would be of particular value to study more precisely the survival of *M. edulis* under adverse conditions in the field.

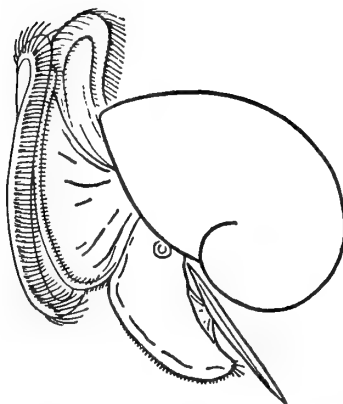
## SUMMARY

1. The survival of *Mytilus edulis* under reduced concentrations of dissolved oxygen and chlorinity at 15°C to 16°C was studied under laboratory conditions.
2. The 14 day  $TL_m$  value for chlorinity was 8.6‰.
3. Nearly all specimens of *Mytilus edulis* lived for 14 days in reduced dissolved oxygen concentrations as low as 0.2 ppm.

4. The number of byssal threads produced was found to be directly related to concentration of chlorinity and dissolved oxygen. The number of threads produced decreased sharply between 14.0‰ and 16.0‰ chlorinity and 0.6 ppm and 0.9 ppm dissolved oxygen.

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## West American Mollusk Types at the British Museum (Natural History)

### IV. CARPENTER'S Mazatlan Collection

BY

A. MYRA KEEN

Department of Geology, Stanford University, Stanford, California 94305

(Plates 55 to 59; 171 Text figures)

IT IS NOW MORE THAN a century since the publication of Philip Carpenter's "Catalogue of the Mazatlan' shells in the British Museum collected by Frederick Reigen." This was a pioneering work, for Carpenter was in the forefront of those who saw potential benefits from the study of geographic distribution. He realized that here, for the first time, was a reasonably complete collection from a single locality (or at least a limited area), and he did his best to examine it in detail. He enumerated nearly 700 species of mollusks from this West Mexican station and described some 255 kinds as new. Unfortunately, the catalogue was published without illustrations, and the 60 plates of camera lucida drawings of the smaller forms that he did prepare remained (with minor exceptions) in manuscript until recently, when the Paleontological Research Institution undertook their reproduction (BRANN, 1966). These plates did not include figures of the larger shells, of which there were nearly a hundred species. BRANN cites published photographs of 6 of these types, and a few others were figured during the 1860's by the iconographers Reeve and Sowerby.

Carpenter's catalogue was the second of his 3 major publications that have been fundamental to all later studies of West American mollusks. However, a century had to elapse before a systematic survey of the actual type specimens that he worked with was initiated. To Dr. Katherine Palmer we owe a lasting debt for having persevered in the task of hunting out those types that had been deposited at institutions other than the British Mu-

seum. All of us had assumed that she would monograph in similar fashion the British Museum material. Therefore, when I went to England for study in 1964, I had no intention of intruding upon her domain of research. The drawings and photographs of Carpenter material that I then made were meant to be for my own use. However, now that Dr. Palmer (*in* BRANN, 1966, p. 3) has indicated that with a trilogy of publications completed she plans no further research on the subject, I realize that my work may supplement the available printed material and can supply, at long last, figures of virtually all of the non-microscopic types. It can also provide some data on sizes of the specimens and an attempt to interpret the species in terms of our modern classification.

One point that I made in a foreword to Brann's paper perhaps should be repeated here, that although Carpenter referred throughout his published catalogue to the "Liverpool Collection," the material was not at any time under the care of the Liverpool Museum. Rather, Liverpool was the docking area to which the major part of Reigen's collection was shipped for sale. Reigen sent another smaller fraction to Le Havre, France. Sylvanus Hanley purchased a part of the latter stock, and some of these specimens later found their way to the British Museum. The part of the "Liverpool Collection" that Carpenter bought was worked over by him, then split into duplicate series, of which the first and best was offered to the British Museum (Natural History) under certain conditions — that the collection remain intact, that it be made available to qualified students, and that it remain as he had arranged and mounted it on glass slides numbered to correspond with the entries in his printed "Catalogue," a copy of which went with the collection. These conditions were accepted, and the collection has remained as a unit.

<sup>1</sup> Technically, the Mexican place-name Mazatlán should be written — as pronounced — with the final syllable accented. However, to be consistent with Carpenter's usage, I have omitted the accent mark throughout this paper. The word "mazatlán," an Amerind term, means "place above the cornfields."

Some of my initially incomplete observations were supplemented during two later brief trips to the British Museum, but there still remain some unanswered questions for future research. The reader, to make full use of the present report, should have at hand the work by Brann, and a copy of Carpenter's "Catalogue," now made available through a reprint edition by the Paleontological Research Institution. Carpenter's drawings having included details of sculpture, it would be duplication of effort if I did the same; I have therefore reduced mine to little more than simple outlines that show the shape of the shells under standard orientation (Carpenter often tilted specimens to bring out apertural features or hide defects). It is gratifying to find how closely, in general, our two sets of camera lucida sketches agree. There has been a tendency to distrust Carpenter's figures because some of the few that were published looked so amateurish. They prove, however, not grossly inaccurate, though perhaps a little distorted, and this gives us more confidence in his drawing of type specimens now lost or deteriorated.

Several problems emerge as one examines the material and the literature about it. First, the date of publication of the "Catalogue." Many workers, including my younger self, interpreted the date at the end of each printed signature as the date of publication of a separate part. IREDALE (Proc. Malac. Soc. London, vol. 12, p. 36, 1916) argued that the date of the entire work must be post-June 1857 for the official edition and later for the Warrington edition issued by Carpenter. In 1961, when I was publishing a paper in the British Museum (N.H.) Bulletin series, I was reluctantly obliged to accept IREDALE's conclusion, for the editor could find no evidence in the British Museum archives of any publication of the work as parts and I could produce no contemporary testimony on the point. Only recently did I notice a statement by Carpenter that should have settled the question long ago. In the bibliographic list introducing a reprint of his papers, CARPENTER (1872, p. xi) cited the "Catalogue of the Reigen Collection, the first edition with preface arranged by Dr. J. E. Gray . . ." and the "Second edition, with author's preface, accompanying duplicate collections of the shells, published simultaneously." Thus, the publication date for both editions must be accepted as not earlier than June, 1857.

A second problem has to do with the area covered by the collection. Did all of it come from the immediate vicinity of Mazatlan? Mr. A. M. Strong (Bull. Southern Calif. Acad. Sci., vol. 48, prt. 2, p. 73, 1949) has noticed (and my own observations are in harmony with his) that the microscopic shells seem to match up with those now taken on the west side of the Gulf of California, notably

in the La Paz area. However, Major Rich, who met Reigen in Mazatlan, had evidence that Reigen did much local collecting, for he recorded that Reigen had so filled his house with decomposing mollusks that the neighbors appealed to the police (CARPENTER, 1864, p. 540). The part of the collection that is now in the British Museum looks to be mainly live-taken, certainly not beach-worn. Carpenter indicated that the microscopic forms were in crevices in large *Spondylus* and *Chama*. He lamented how few of these there were, for before he got to Liverpool, most of the large shells had been sold to an innkeeper who wanted them for decoration; it was a bitter disappointment to Carpenter to learn that the washings from these were discarded, thus destroying the chance for the study of the countless small attached and nestling specimens. Whether the large shells had all been gathered at Mazatlan or whether they had been brought there from elsewhere in the Gulf is a problem for further research. Lime for mortar used in building was gotten from shells — Carpenter commented on this (1857b, p. 153). We therefore need to know something more about the distribution, past and present, of large *Spondylus* and *Chama* and the amount of commercial exploitation.

Precise measurements of the types turned out to be more of a problem than I had anticipated when I set out to photograph each larger specimen with a millimeter scale in the picture and to calibrate each microscope-lens combination by reading the resulting magnification of a millimeter scale. In his preface Carpenter stated that all his measurements were in inches and decimal parts. Later (1865a, p. 133), he described the inch as 2.53 cm. We normally take it as 2.54 cm or 25.4 mm, but this is not a critical difference. As soon as one begins converting his decimal parts to millimeters one realizes that he was dealing with very small shells, and it is remarkable that he was able to read his scale as accurately as he did. However, when I checked my readings of dimensions against his I found some disharmonies. Fortunately, I had both photographed and drawn a number of the types, and this gave a basis for a comparative analysis that showed my camera lucida readings to be about 10% too high and his to be slightly low. Because my millimeter scale was thinner than the glass slides, I would have changed focus (and therefore image size) between taking the scale reading and making the drawing. If he used the same method for getting readings and if his scale was thicker (which is likely, as plastic was not then available), this would account for the average 15% discrepancy between his readings of size and mine. In any case the discrepancy is not of a magnitude to be of real consequence in making identifications, for it is within the range of expected variations in size of specimens. In a few cases

Carpenter seems to have misread his scale, however, or there is a typographical error in his text. I have called attention to these in my discussions of species.

A minor problem has to do with the correct citation of some of the specific names. Carpenter adopted the practice – later followed by Dall in Bulletin 112 of the U. S. National Museum – of citing subgeneric names as if they were generic, making adjectival specific names agree in gender with the subgeneric rather than the generic name. This has sometimes been a source of confusion in the citations by later authors, notably for the genera *Terebra*, *Turbonilla*, and *Odostomia*.

### FORMAT

Carpenter's catalogue was arranged according to a system, but the sequence of family and ordinal groups was markedly different from modern usage. He ranked chitons, for example, as prosobranch gastropods. Once he had arrived at his classification, he numbered the species and also the mounts or tablets, and he saw no need for further indexing. Maintaining the original material according to his scheme is convenient and desirable in the museums where it is housed, and the Brann publication was obliged to follow the same pattern. For the present report it seems preferable to attempt a fresh start. I have rearranged the species into modern systematic order insofar as possible, with an alphabetical index for cross-referencing. Each entry is given a paragraph number (in bold face numerals). The name is cited exactly as Carpenter spelled it (even to disagreement of the adjectival endings), with page reference (unless otherwise noted) to the Mazatlan Catalogue. Following an equality sign is my interpretation of the correct modern assignment. Tablet numbers are as listed by Carpenter, with number of specimens and their present type status. The entry in square brackets is the size given by Carpenter (longest dimension, whether height or diameter), converted to millimeters. The Carpenter figures now available are cited as "BRANN," without repeating the date. My commentary includes notes on present condition of the specimens, on morphology, on nomenclatural problems, and on figures by other authors.

It may seem that in the inventory of type specimens I have been rather too liberal in the use of the term "syntype." The natural assumption on the part of authors who figured or cited Carpenter's material has been that when a single specimen was on a Carpenter mount in the British Museum it would automatically be the holotype, and any other distributed material would be paratype. However, Carpenter did not select type specimens

in the modern sense. He only said "the specimen" when he had but a single shell. Thus, we must consider his type lots, when there were two or more shells, syntypic. It is desirable that the British Museum specimens be designated as lectotypes if they are in a good state of preservation, and I have done this for many lots.

### ACKNOWLEDGMENTS

A fellowship from the John Simon Guggenheim Foundation provided my travel expenses during 1964 and 1965, for which I am grateful. I wish also to thank the officials and staff of the British Museum (Natural History) for the privilege of use of the collections. Words of high praise are due to the curators whose care of the material during the last century has kept so much of the Carpenter collection in prime condition, this in spite of two world wars and numerous museum-cabinet transfers.

I am indebted for helpful advice and suggestions especially to Leo G. Hertlein, Ronald Ives, Allyn G. Smith, Judith Terry, and Spencer Thorpe; three photographs are from color slides made in 1962 by Elaine Reeves (now Mrs. François Padovani); my camera lucida sketches were turned into finished line drawings by Perfecto Mary, artist-technician at Stanford, who was of great assistance to me in the preparation of the plates. To all of these persons and to the many others who helped in less evident ways, my thanks.

### PELECYPODA

#### ARCIDAE

1. *Byssosarca vespertilio*, p. 140  
= *Barbatia lurida* (SOWERBY, 1833)  
(Plate 55, Figure 1)

Tablet 651, holotype. [33 mm].

No distinctive characters seem to justify this as a separate form.

2. *Arca bifrons*, p. 134  
= *Anadara (Cunearca) bifrons* (CARPENTER, 1857)  
(Plate 55; Figures 18 a-c)

Tablet 631, fragments only. [43 mm].

Two syntypes from the Cuming Collection, now in the British Museum's Type Collection, are illustrated here; the larger may be the one figured by OLSSON (1961, pl. 9, fig. 3 b) as "type"; it is here chosen as lectotype.

## MYTILIDAE

3. *Mytilus multiformis*, p. 118

= *Brachidontes* (*Scolimytillus*) *multiformis* (CARPENTER, 1857)

(Plate 55, Figures 5 a-b)

Tablets 540 - 552, numerous syntypes. [11.5 mm]. BRANN: plt. 15, fig. 168 (also OLSSON, 1961, plt. 17, fig. 11, with selection as lectotype).

Carpenter listed 13 tablets of syntypes; specimens from 543 and 551 are figured here; no. 546 is attached to a specimen of the next species.

4. *Mytilus palliopunctatus*, p. 118 (as of DUNKER)

= *Choromytilus palliopunctatus* (CARPENTER, 1857)

(Plate 55, Figures 4 a-b)

Tablets 528 - 539 (539 here figured). [90 mm]. BRANN: plt. 15, fig. 167 (juveniles from tablet 528).

Although the specific name was credited to Dunker, he had not validated it; thus it is to be attributed to Carpenter.

5. *Modiola ?brasiliensis* var. *mutabilis*, p. 122

= *Mytella guyanensis* (LAMARCK, 1819)

(Plate 55, Figures 20 a-b)

Tablets 559 - 565 (tablet 559, 2 adolescent syntypes figured), 11 syntypes. [63 mm]. BRANN: plt. 15, fig. 171-b (juvenile from tablet 565).

If the West American form ever proves distinct from that of the Atlantic, Carpenter's specific name would be available for use.

6. *Lithophagus aristatus gracilior*, p. 129

= *Lithophaga aristata* (DILLWYN, 1817)

(Plate 55, Figure 9)

Tablet 601, 7 valves, syntypes [29 mm]. BRANN: plt. 16, fig. 176.

None of the valves is now complete. However, they collectively show that the form falls within the range of variation of the species. Carpenter's enlarged drawing exaggerates the dorsal angle.

7. *Lithophagus aristatus tumidior*, p. 129

= *Lithophaga aristata* (DILLWYN, 1817)

(Plate 55, Figures 8 a-b)

Tablets 602 - 603, 7 syntypes. [39 mm]. BRANN: plt. 16, fig. 176 (juvenile, enlarged, from tablet 602).

Tablet 603 has one large specimen (here figured), very tumid, the incrustation wide as well as long; two smaller specimens are of the more usual form of *L. aristata*.

8. *Lithophagus calyculatus*, p. 124

= *Lithophaga* (*Stumpiella*) *calyculata* (CARPENTER, 1857)

(Plate 55, Figures 16 a-b)

Tablet 571, holotype. [9.2 mm]. BRANN: plt. 16, fig. 174.

SOOT-RYEN (1955, p. 93; plt. 10, figs. 61 - 63) seems to have identified this form correctly.

9. *Lithophagus* (*Leiosolenus*) *spatiosus*, p. 130

= *Lithophaga* (*Leiosolenus*) *spatiosa* (CARPENTER, 1857)

(Plate 55, Figures 7 a-b)

Tablet "605" [606\*], syntype. [38 mm].

Carpenter (p. 131) cites tablet 605 as having a young shell and a fragment; on p. 550 he states that tablet 605 contains the original specimen presented by R. Derbyshire. A specimen with the stated dimensions is in the collection, the number on the tablet being "606\*."

SOOT-RYEN (1955, plt. 10, fig. 59) has figured similar material. Carpenter's shell appears more slender because it has curled in drying and the ventral margin has bent inward.

10. *Crenella coarctata*, p. 123 (ex DUNKER MS)

= *Gregariella coarctata* (CARPENTER, 1857)

(Text figure 1)

Tablets 566 - 567, originally 6 syntypes. [4.5 mm].

BRANN: plt. 15, fig. 172.

Carpenter credits the name to Dunker, who had not validated it. On tablet 566 are 3 juvenile pairs about 2 mm long. One loose semi-adult 4 mm long may be from tablet 567. The other specimens are missing, represented only by glue smears on the mount. The small shell resembles *G. chenui* as to outline, with 15 radial ribs.

## ISOGNOMONTIDAE

11. *Isognomon janus*, p. 151

= *Isognomon janus* CARPENTER, 1857

(Plate 55, Figure 10)

Tablets 689 - 690, 4 syntypes. [28 mm, central area only]. BRANN: plt. 17, fig. 206 (juvenile, tablet 689).

As the legend on tablet 690 states, "*Isognomon janus* on *I. chemnitzianum*" and there is but a single specimen on the mount, I assumed that the *I. janus* syntype was lost, but I photographed the tablet anyway. Later study of the picture showed that not only does the specimen have the dimensions cited by Carpenter but it has only 5 ligamental sockets, whereas *I. chemnitzianum* has 6 to 12. Therefore the shell in my figure evidently is one that had been on *I. chemnitzianum* before mounting and is a syntype of Carpenter's species.

## OSTREIDAE

12. *Ostrea conchaphila*, p. 161

= *Ostrea conchaphila* CARPENTER, 1857

Tablets 715 - 734, numerous syntypes. [26 mm]. Tablet 728 here selected as lectotype.

The lectotype was figured by HERTLEIN & STRONG, (1955, plt. 3, figs. 29 - 30) as "holotype." Part of the syntype lot was figured by SOWERBY in REEVE, 1871 (Conch. Icon., vol. 18, plt. 28, sp. 69).

13. *Ostrea palmula*, p. 163

= *Ostrea palmula* CARPENTER, 1857

(Plate 55, Figure 6)

Tablets 735 - 737; largest syntype, no. 737, here selected as lectotype [58 mm].

The lectotype here selected was figured by HERTLEIN & STRONG, 1946 (Zoologica, vol. 31, p. 76; plt. 1, fig. 14) as "holotype."

## SPONDYLIDAE

14. *Spondylus calcifer*, p. 152

= *Spondylus calcifer* CARPENTER, 1857

Tablets 692 - 699 (692, juvenile, with query). [About 180 mm].

Authors have identified this species correctly. None of the syntype specimens is in good enough condition to photograph, for they consist mostly of broken and cut fragments, what was left after Carpenter had extracted the borers and nestlers from the surface layers.

15. *Plicatula penicillata*, p. 155

= *Plicatula penicillata* CARPENTER, 1857

(Plate 55, Figures 2 a-b)

Tablet 701, two syntypes. [28 mm].

The smaller syntype shows brown pencilling on the outer layer; the larger is white, triangular, fine-ribbed, attached to a specimen of *Crepidula aculeata*. The form was figured by SOWERBY in REEVE (1873, Conch. Icon., vol. 19, plt. 1, fig. 3).

## ANOMIIDAE

16. *Placunanomia pernoides*, p. 164

= *Pododesmus (Tedinia) pernoides* (GRAY, 1853)

(Plate 55, Figures 14 a-c)

Tablets 745 - 748, two syntypes, complete, two odd valves, one broken, all on one mount, of which the largest, no. 748, may be taken as lectotype. [46 mm].

If, as seems possible, this form proves distinct from Gray's, a new name will be needed, for Carpenter's spe-

cies, named as new, seems to be conspecific with Gray's. The difference in outline between Mexican and Californian material may be only a matter of difference in habitat, for the Californian specimens, favoring pholad holes, are distorted by the cramped quarters, whereas Mazatlan specimens, not having borers as associates, have had to attach in more open sites.

17. *Placunanomia claviculata*, p. 166

= *Anomia peruviana* ORBIGNY, 1846

(Plate 55, Figures 15 a-b)

Tablet 750, syntype, both valves. [37 mm]. BRANN: plt. 17, fig. 218.

This seems to be a thin white form of *Anomia peruviana* grown on a smooth surface that had been encrusted with a few small serpulid worm tubes. As the anomiid grew out over the tubes a strong trace was left on the shell, and the supposed "clavicle" of the lower valve seems to me to be only a reflection of such a tube. Carpenter's dimensions must have been taken from the odd valve he mentions, for they are a third larger and are wider for the length than the mounted pair.

## ASTARTIDAE

18. *Gouldia varians*, p. 83

= *Crassinella varians* (CARPENTER, 1857)

(Text figure 2)

Tablets 415 - 419, 22 syntypes (none now on 418). [2.2 mm]. BRANN: plt. 9, fig. 117.

Shells small, triangular, nearly smooth, with a brown stripe or spot posteriorly.

## CARDITIDAE (?)

19. *Cardium lucinoides*, p. 96

? = *Cardita* sp.

Text figure 3)

Tablet 463, holotype. [1.0 mm]. BRANN: plt. 11, fig. 135 ["136" on plate].

The minute shell, a right valve, is probably too young for positive determination. There are 12 ribs with beaded sculpture and a tinge of brown color toward their ends; the hinge is not well preserved, so that details as to dentition are unclear, but it does not seem to be a cardiid.

## CORBICULIDAE

20. *Cyrena olivacea*, p. 114

= *Polymesoda (Egeta) olivacea* (CARPENTER, 1857)

(Plate 55, Figures 12 a-c)

Tablets 505 - 511, 17 syntypes (2 here figured from tablet 509). [60 mm].

There is some variation in outline among the syntypes as well as in size.

#### PISIDIIDAE (SPHAERIIDAE of authors)

21. *Cycladella papyracea* CARPENTER, 1865 b, p. 270  
= *Sphaerium* sp., cf. *S. trigonare* (SAY, 1829)  
(Plate 55, Figures 3 a-b)

Tablet 119 (fragments, as cited by CARPENTER, 1865; now nearly disintegrated).

The type locality is Mazatlan, but the genus and species was not described in the Mazatlan Catalogue. Carpenter tentatively assigned the genus *Cycladella* to KELLIDAE. The holotype had been among the Reigen material purchased by S. Hanley, and it came to the British Museum from H. Harvey, Esq.; it is registered as no. 1907.12.30. 117. I am indebted to Mr. Peter Dance, then of the British Museum staff, for the reallocation of the form as non-marine; he ably demonstrated that hinge and sculpture match those of specimens of *Sphaerium* from Mexico, and Dr. Dwight Taylor suggested that Say's species is the most likely candidate for comparison. The generic name *Cycladella* therefore may be removed from marine lists, for it falls as a synonym of *Sphaerium* SCOPOLI, 1777. The specific name is not apt to prove useful either.

#### Explanation of Text figures 1 to 22

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 1: *Crenella coarctata*. Syntype, interior left valve. Length, 4 mm (x 7).

Figure 2: *Gouldia varians*. Syntypes, a) exterior; b) interior. Height, 2.7 mm (x 8).

Figure 3: *Cardium lucinoides*. Holotype, interior of right valve. Length, 1.4 mm (x 13).

Figure 4: *Circe margarita*. Lectotype. a) interior, left valve; b) interior, right valve; c) enlarged sketch. Length, 1.5 mm (x 15).

Figure 5: *Lucina mazatlanica*. Syntypes. a) interior, left valve (x 9); b) interior, right valve (x 8); c) exterior, right valve (x 5). Length, 2 mm to 4 mm.

Figure 6: *Lepton dionaeum*. Holotype, interior of left valve. Length, 1.8 mm (x 12).

Figure 7: *Lepton umbonatum*. Syntypes, a) sketch of recrystallized adult left valve (x 9); b) and c), interior of juvenile shell (x 8). Length of adult, 2.6 mm; of small pair, 1.8 mm.

Figure 8: *Montacuta chalconica*. Holotype. a) enlarged sketch of hinge, right valve; b) interior, right valve (x 17); c) exterior (x 21). Length, 1.0 mm.

Figure 9: *Montacuta elliptica*. Syntype, right valve interior. Length, 4.0 mm (x 6).

Figure 10: *Montacuta obtusa*. Holotype. a) right valve; b) left valve. Length, 1.7 mm (x 13).

#### BERNARDINIDAE

22. *Circe margarita*, p. 81

= *Bernardina margarita* (CARPENTER, 1857)  
(Text figure 4)

Tablet 412, one odd valve and 3 entire syntypes (the largest here selected as lectotype). [1.8 mm]. BRANN: plt. 9, fig. 114.

Microscope examination of the type lot in 1964 corrects my hand-lens assignment to *Lasaea* (KEEN, 1958, p. 622). The hinge is close to that of *Bernardina bakeri* DALL, 1910, type of the genus, from southern California. This extends the range of the genus into the Panamic province, and material in the Stanford University collection taken by diving at the Tres Marias Islands and Banderas Bay in 1965 extend it further. The form proves to be ovoviviparous, the shell small, concentrically ridged, white to cinnamon brown variously tinged and rayed with pink, especially near the beak.

23. *Circe subtrigona* p. 82

= *Halodakra subtrigona* (CARPENTER, 1857)

Tablet 413, 4 syntypes. [2.8 mm]. BRANN: plt. 9, fig. 115.

HAAS (1945, Fieldiana, Zoology, vol. 31, no. 2, pp. 4 to 5), discussing a "paratype" at Chicago Museum pointed out that on account of the sunken ligament this form is neither a venerid nor petricolid as had been

Figure 11: *Montacuta subquadrata*. Syntype. Left valve. Length, 3.8 mm (x 6).

Figure 12: *Pythina sublaevis*. Syntype. Left valve. a) exterior (x 9); b) interior (x 12). Length, 2.2 mm.

Figure 13: *Cardium alabastrum*. Holotype, exterior, left valve. Length, 3.0 mm (x 7).

Figure 14: *Cardium rotundatum*. Holotype, interior, right valve. Length, 1.8 mm (x 13).

Figure 15: *Tapes squamosa*. Lectotype, exterior, left valve. Length, 2.8 mm (x 9).

Figure 16: *Rupellaria exarata*. Syntype, interior, right valve. Length, 5 mm (x 5).

Figure 17: *Rupellaria linguafelis*. Syntype. a) hinge, right valve; b) interior, left valve. Length, 3.1 mm (x 8); c) exterior, right valve. Length, 4 mm (x 6).

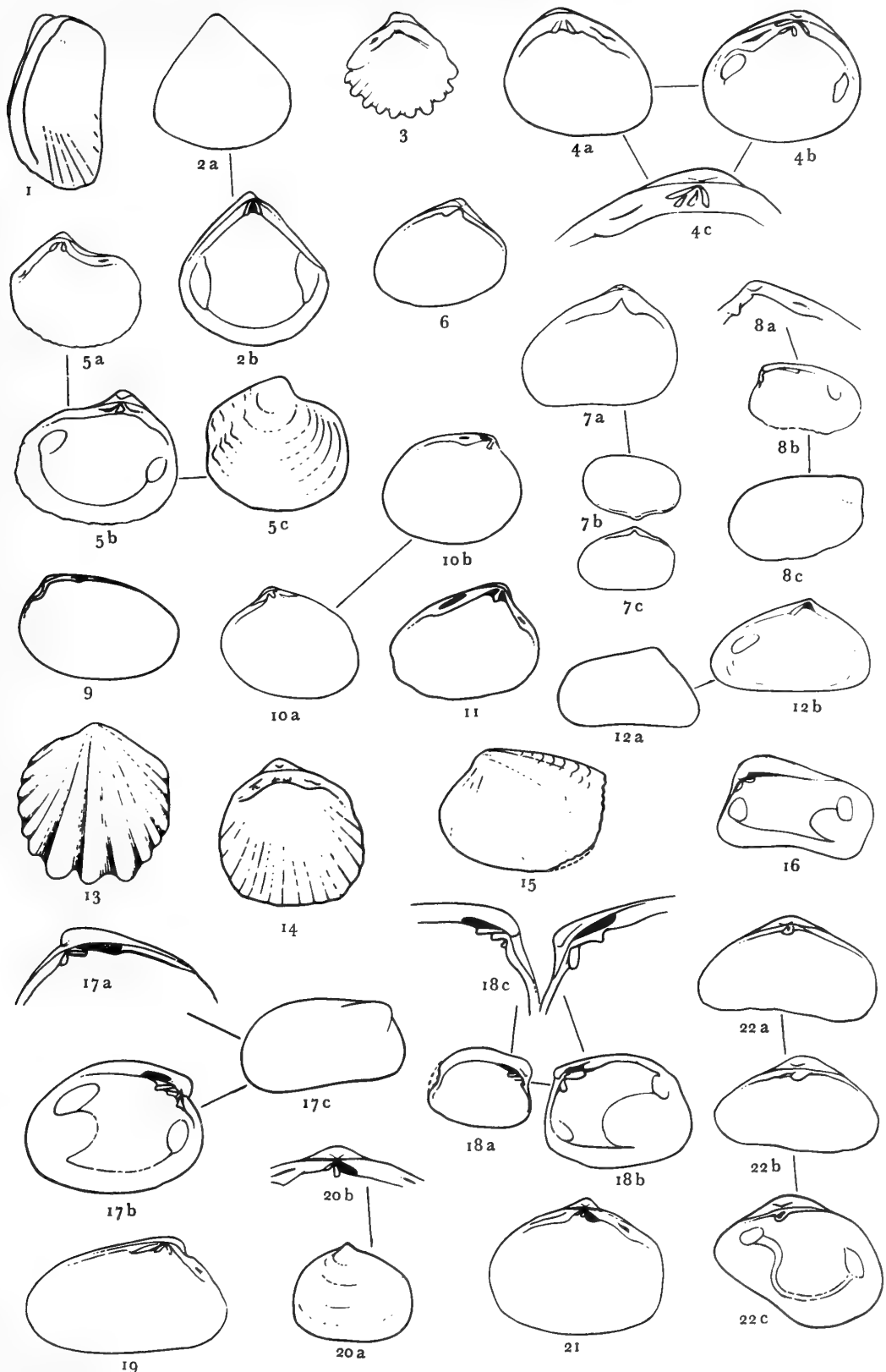
Figure 18: *Naranio scobina*. a) Holotype, left valve. Length, 3.5 mm (x 5); b) hypotype, right valve. Length, 4 mm (x 6); c) enlarged hinges.

Figure 19: *Tellina donacilla*. Holotype, right valve. Length 4 mm (x 7).

Figure 20: *Tellina lamellata*. Syntype. a) exterior. Length, 3.5 mm (x 6); b) enlarged sketch of hinge.

Figure 21: *Tellina regularis*. Holotype, right valve. Length 4 mm (x 7).

Figure 22: *Sphaenia fragilis*. Three syntypes, left valves, showing resilifer. Length of largest, 8 mm (x 3.5).



thought, and he suggested semelid affinities. OLSSON (1961, p. 319; plt. 27, figs. 1-1c) proposed a generic name for it, *Halodakra*, but he was uncertain as to family placement. Although superficially *Bernardina* and *Halodakra* are not strikingly similar, they do have enough in common so that I have allocated them to the family BERNARDINIDAE (KEEN, 1963, p. 91).

The species ranges from Baja California to Peru and is readily recognizable by its chevron-shaped color markings, well shown in Olsson's figures; both Carpenter and Olsson have good figures of the hinge.

#### LUCINIDAE

##### 24. *Lucina excavata*, p. 98

= *Lucina* (*Here*) *excavata* CARPENTER, 1857  
(Plate 56, Figure 23)

Tablet 468, originally 2 syntypes. [10.4 mm]. BRANN: plt. 12, fig. 140.

Only a single valve remains. It is worn but recognizable and has been correctly identified by modern workers.

##### 25. *Lucina prolongata*, p. 100

= *Lucina* (*Cavilinga*) *prolongata* CARPENTER, 1857  
(Plate 56, Figures 22 a-d)

Tablet 474, 7 syntypes. [4 mm]. BRANN: plt. 12, fig. 145.

The species seems to have been correctly identified by modern workers. Carpenter's drawing also has been reproduced by OLSSON (1961, plt. 31, fig. 10).

##### 26. *Lucina mazatlanica*, p. 99

= *Lucina* (*Parvilucina*) *mazatlanica* CARPENTER, 1857  
(Plate 56, Figures 29 a-b; Text figures 5 a-c)

Tablet 472, originally 15 syntypes (now 6 pairs, 2 odd valves). [4 mm]. BRANN: plt. 12, fig. 144.

The shell is thin, with a lunule longer in most syntypes than is shown in the figure in my book (KEEN, 1958, fig. 193), but the form seems to have been correctly identified. OLSSON (1961, plt. 31, fig. 3) reproduced Carpenter's drawing.

##### 27. *Lucina pectinata*, p. 98 (non C. B. ADAMS, 1847)

= *Ctena mexicana* (DALL, 1901)

(Plate 56, Figure 21)

Tablet 470, holotype. [12.5 mm].

The single valve is somewhat chipped but in recognizable state.

#### DIPLODONTIDAE

##### 28. *Diplodonta ?semiaspera*, var. *discrepans*, p. 103

= *Diplodonta discrepans* CARPENTER, 1857  
(Plate 56, Figures 30 a-d)

Tablet 481, holotype. [7.9 mm]. BRANN: plt. 12, fig. 150b.

The single specimen is young but not juvenile. Carpenter's drawing was reproduced by OLSSON (1961, plt. 32, fig. 7a), who considers the species distinct and extends the range south to Colombia. Carpenter was hesitant about describing this form on account of the variability he noted in a cluster of diplodontas found within a single cavity, a mixture of what might otherwise be assigned to several distinct species. The largest specimen on tablet 479, his typical "*D. semiaspera*," is punctate and shows the wide hinge and sunken ligament of what has recently been separated out as a new genus and species, *Pegma-pex phoebe* BERRY, 1960 (figured by BRANN on plt. 12, fig. 150 and by OLSSON from Carpenter's manuscript drawings on plt. 32, fig. 3d).

#### LEPTONACEA

##### 29. *Lepton clementinum*, p. 110

= ?*Mysella clementina* (CARPENTER, 1857)

Tablet 498, holotype. [0.9 mm]. BRANN: plt. 14, fig. 157.

The holotype is now missing from the tablet, one of the few that is irrevocably lost. Identification must depend, therefore, on Carpenter's camera lucida drawing, which fortunately includes both the exterior and the interior views.

##### 30. *Lepton dionaeum*, p. 111

= ?*Mysella dionaea* (CARPENTER, 1857)  
(Text figure 6)

Tablet 499, holotype. [1.5 mm]. BRANN: plt. 14, fig. 158.

The holotype consists of one valve, in poor condition; no trace of pallial line or muscle scars is now visible.

##### 31. *Lepton umbonatum*, p. 111

= ?*Mysella umbonata* (CARPENTER, 1857)  
(Text figure 7)

Tablet 500. [2.0 mm]. BRANN: plt. 14, fig. 159.

Of the two specimens originally on the mount, the adult is now encrusted with crystals of calcite; a pair of young, later added (CARPENTER, 1865 b, p. 269), are in good condition but too immature to be of any help in interpreting morphology. Thus, Carpenter's figure is the only reliable clue.

32. *Montacuta chalconica*, p. 531

?=*Kellia chalconica* (CARPENTER, 1857)  
(Text figure 8)

Tablet 2529, holotype. [0.7 mm]. BRANN: plt. 10, fig. 694.

The single valve is a nepionic shell, thin and white, the hinge showing two teeth. Carpenter's drawing must be taken as accurate and indicates that already the valve had been damaged along the lower margin.

33. *Montacuta elliptica*, p. 113

?=*Lepton ellipticum* (CARPENTER, 1857)  
(Text figure 9)

Tablet 502, 2 syntypes. [3.3 mm]. BRANN: plt. 10, fig. 161.

The shell is so thin that the sculpture, which is of fine incremental lines, shows through to the inside.

34. *Montacuta obtusa* CARPENTER, 1865 b, p. 270

=*Bornia* (?) *obtusa* (CARPENTER, 1857)  
(Text figure 10)

Tablet 2530, syntype. [1.5 mm]. BRANN: plt. 14, fig. [706].

In 1857 (p. 550) Carpenter cited tablet 2530 as "*Crenella* sp. ind." and mentioned a "hairy epidermis on the posterior part where it lies in radiating lines, while it is concentric on the anterior, decussated towards the middle," evidently an erroneous reference intended for his *Gregariella coarctata*. My notes on the true tablet no. 2530 are: "Exterior smooth, somewhat iridescent or lustrous due to the coating of glue; there are faint radial and concentric striae near the ventral margin."

35. *Montacuta subquadrata*, p. 113

see no. 55

36. *Pythina sublaevis*, p. 112

=*Pythinella sublaevis* (CARPENTER, 1857)  
(Text figure 12)

Tablet 501, 2 syntypes. [2.0 mm]. BRANN: plt. 14, fig. 160; figure also reproduced by OLSSON, 1961, p. 238; plt. 83, fig. 12.

One valve of the type material is now badly recrystallized and broken; the drawing is from the hinge of the other, which is intact. The form has recently been recognized and figured from Panama (OLSSON, 1961, plt. 36, fig. 11).

37. *Lasea trigonalis*, p. 109

=*Orobitella trigonalis* (CARPENTER, 1857)  
(Plate 56, Figures 28 a-c)

Tablet 496, 2 syntypes, one odd valve. [7.6 mm]. BRANN: plt. 14, fig. 155.

One pair of valves is more trigonal than the other.

All valves lack the periostracum that probably was present. In shape the shell is somewhat similar to *Orobitella* (*Isorobitella*) *singularis* KEEN, 1962 from San Quintín Bay, Baja California, but with a less massive hinge. The pair of valves in Figure 28 a-b (Plate 56) is here selected as lectotype.

38. *Lasea oblonga*, p. 109

=*Orobitella oblonga* (CARPENTER, 1857)  
(Plate 56, Figure 24)

Tablet 497, holotype. [5.1 mm]. BRANN: plt. 13, fig. 156.

The single valve still shows a remnant of periostracum. The species is close to *Sportella stearnsii* DALL, 1899 in outline but less elongate.

## CHAMIDAE

39. *Chama ?frondosa* var. *forficata*, p. 89

=*Chama frondosa mexicana* CARPENTER, 1857  
(Plate 56, Figures 31 a-b, 35 a-b)

Tablets 439 - 443, 6 syntypes.

Only two of the several syntype specimens are complete enough and in good enough condition to provide recognizable figures. The variety seems not to be morphologically valid, for the only constant feature Carpenter cited was presence of an ashy periostracum.

40. *Chama ?frondosa* var. *mexicana*, p. 87

=*Chama frondosa mexicana* CARPENTER, 1857

Tablets 425 - 438, about 30 syntypes. [140 mm]. BRANN: plt. 10, fig. 121.

Most of the specimens were less than perfect when collected. There has been no problem in recognition of the form from Carpenter's description. Sixteen juvenile shells are on tablets 425 - 430.

## CARDIIDAE

41. *Cardium alabastrum*, p. 99

=*Trigoniocardia granifera* (BRODERIP & SOWERBY, 1829)  
(Text figure 13)

Tablet 461, holotype. [3.0 mm]. BRANN: plt. 11, fig. 133.

The shell is juvenile, with ribs beaded on the anterior slope and with interspaces between ribs concentrically striate.

42. *Cardium rotundatum*, p. 531

=*Trachycardium (Mexicardium) panamense* (SOWERBY, 1833)

(Text figure 14)

Tablet 2522, holotype. [1.6 mm]. BRANN: plt. 11, fig. 687.

The valves of this juvenile shell had come loose from

the mount. Although slightly recrystallized, the shell is not yet seriously damaged, and surface details can still be made out.

#### VENERACEA

#### 43. *Trigona humilis*, p. 57

= *Transennella tantilla humilis* (CARPENTER, 1857)

(Plate 55, Figures 17 a-c)

Tablet 244, 6 syntypes. [4.0 mm].

This is the southern form of *Transennella tantilla* (GOULD, 1853), from which it differs by being smaller, longer, smoother, and more brightly colored. The largest specimen (Plate 55, Figures 17 a-b) here chosen as lectotype, shows clearly the oblique grooving of the inner ventral margin.

#### 44. *Dosinia annae*, p. 61

= *Dosinia annae* CARPENTER, 1857

"= *Dosinia (Dosinia) semiobliterata* DESHAYES, 1853"

teste FISCHER-PIETTE & DELMAS, 1967

(Plate 56, Figures 36 a-b)

Tablet 258, 2 syntypes, "A young and a full-grown specimen." [62 mm].

Authors seem to have interpreted the species correctly. An additional immature shell has subsequently been added to the lot; as Carpenter gave dimensions only for

the adult, the uncertainty as to which was added may be evaded by selecting the full-grown (the largest) specimen as lectotype.

In a work received while this paper was in press, FISCHER-PIETTE & DELMAS (Mém. Mus. Nat. d'Hist. Nat., n. s., sér. A, Zool., vol. 47, fasc. 1, pp. 69-70, 1967), revising the genus *Dosinia*, have shown that the supposed Australian *Dosinia semiobliterata* DESHAYES, 1853 actually seems to be *D. annae* with an erroneous locality. The subgenus *Dosinia* does not occur in Australia but is confined to the tropical American region. Under Article 23 (b) of the International Code of Zoological Nomenclature, this would qualify as a *nomen oblitum* that should be brought to the attention of the International Commission. FISCHER-PIETTE & DELMAS (plt. 11, figs. 4-6) figure the holotype of the Deshayes species; it does indeed very closely match my photographs of the type material of *D. annae*.

#### 45. *Clementia gracillima*, p. 54

*nomen dubium*

Tablet 216. [3.3 mm].

The specimen has recrystallized and is now unrecognizable. Unfortunately, Carpenter did not make a drawing, and his brief description gives little real clue as to the morphology.

### Explanation of Plate 55

All specimens are in the British Museum (Natural History), Mollusca Section. They were photographed in place on glass mounts.

Generic and specific names are as cited by CARPENTER.

Figure 1: *Byssarca vespertilio*. Holotype. a) exterior; b) interior. Length, 34 mm (x 1).

Figure 2: *Plicatula penicillata*. Syntype (smaller of two specimens). Length, 23 mm (x 1).

Figure 3: *Cycladella papyracea*. Holotype. a) interior; b) exterior. Photograph by Elaine Reeves. Length, 3.5 mm (x 8).

Figure 4: *Mytilus palliopunctatus*. Interior of one syntype, a small adult. Length, 65 mm (x 0.7).

Figure 5: *Mytilus multiformis*. Two paralectotypes. a) length 10 mm (x 3); b) length 12 mm (x 3).

Figure 6: *Ostrea palmula*. Lectotype (here selected); interior of right valve. Length, 60 mm (x 0.7).

Figure 7: *Leiosolenus spatiosus*. Syntype, adult. a) exterior; b) interior. Length, 38 mm (x 1).

Figure 8: *Lithophagus aristatus tumidior*. Syntype, interior. a) left valve; b) right valve. Length 40 mm (x 1).

Figure 9: *Lithophagus aristatus gracilior*. Interior of one of 7 broken syntype valves. Length (incomplete), 15 mm (x 3).

Figure 10: *Isognomon janus*. Syntype. Maximum diagonal length, 47 mm (x 1).

Figure 11: *Narano scobina*. a) Holotype, left valve. Length, 3.5 mm; b) Hypotype, right valve. Length, 4.5 mm (x 3.8).

Figure 12: *Cyrena olivacea*. Two syntypes. a), b), interior, left valve and right valve. Length, 35 mm; c) exterior, left valve. Length, 50 mm (x 0.6).

Figure 13: *Tapes squamosa*. Syntype (here selected as lectotype), left valve. Length, 2.9 mm. a) (x 4); b) (x 7).

Figure 14: *Placunanomia pernoides*. Lectotype (here selected). a, b) right and left valves, interior. Length, 52 mm; c) Paralectotype, interior, left valve. Length, 52 mm (x 0.6).

Figure 15: *Placunanomia claviculata*. Syntype, maximum length 27 mm (x 1.1).

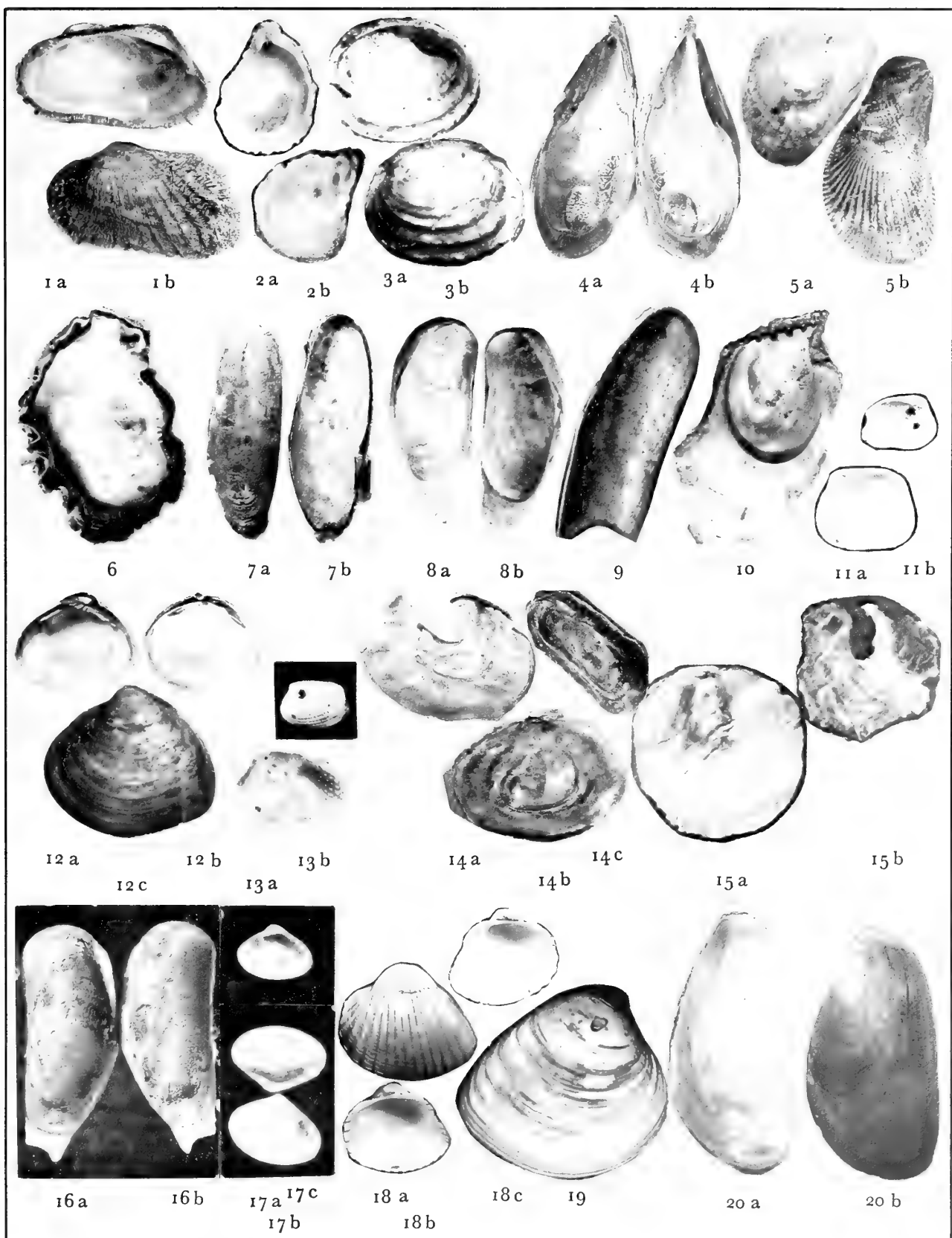
Figure 16: *Lithophagus calyculatus*. Interior of holotype. Length 8.4 mm (x 5).

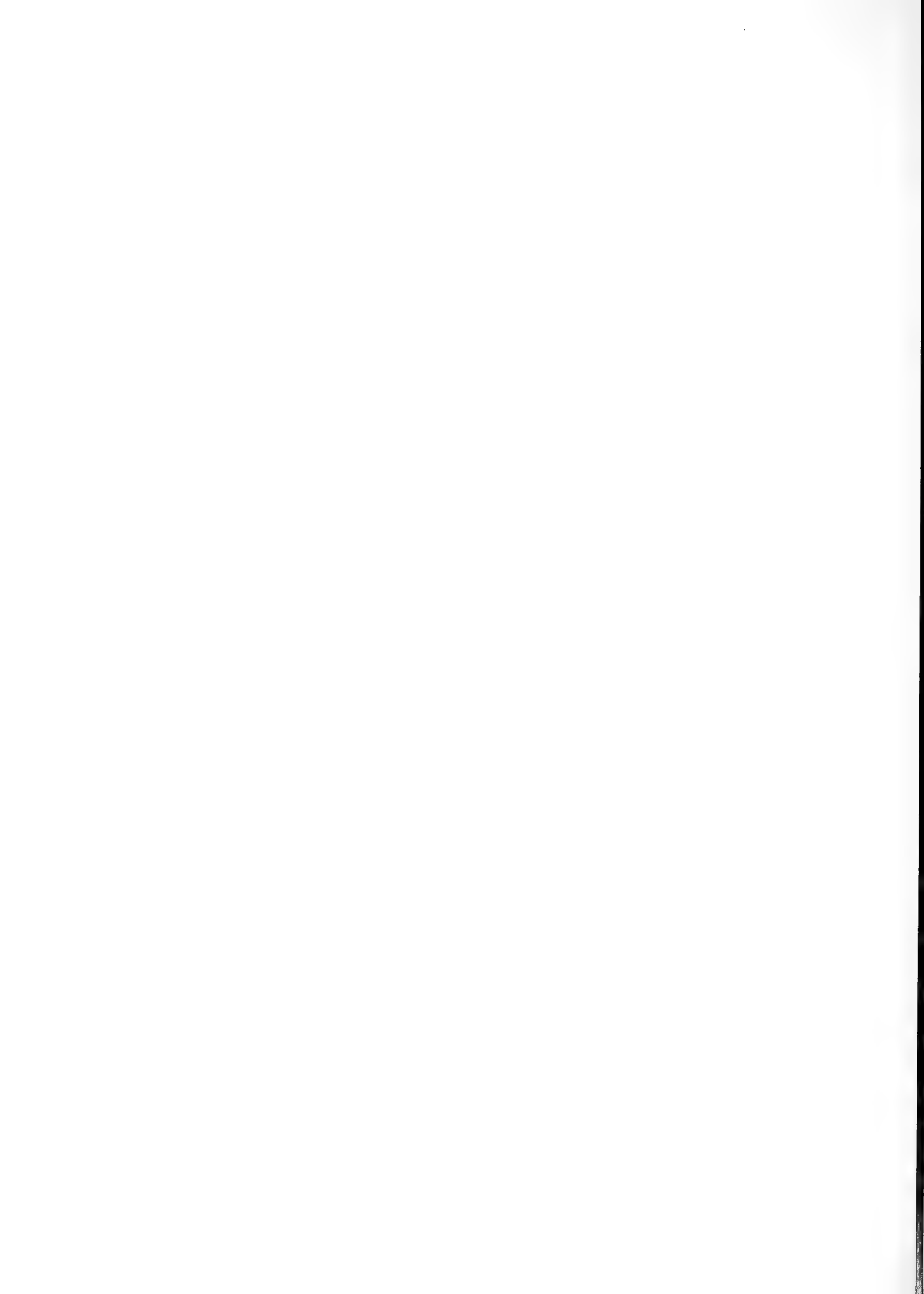
Figure 17: *Trigona humilis*. a, b) lectotype, interior of paired valves. Length, 4 mm; c) lectoparatype. Length, 3.2 mm (x 4.2).

Figure 18: *Arca bifrons*. Two syntypes, Cuming collection. a) here chosen as lectotype, exterior. Length, 43 mm; b, c) interior. Length, 33 mm (x 0.6).

Figure 19: *Venus cortezi*. Holotype, from Guaymas, Mexico. Length, 61 mm (x 0.6).

Figure 20: *Modiola mutabilis*. Two syntypes, sub-adult. a) interior, left valve. Length, 44 mm; b) exterior, right valve. Length 42 mm (x 1).





46. *Tapes squamosa*, p. 78

= *Timoclea (Glycydonta) squamosa* (CARPENTER, 1857)

(Plate 55, Figures 13 a-b; Text figure 15)

Tablet 372, 3 valves. [2.3 mm]. BRANN: plt. 9, fig. 111.

OLSSON (1961, p. 309) recognizes this small chionid as ranging from southern California to Peru. After restudying Carpenter's type and comparing my figures with material very like it in the Stanford collection, from the La Paz area, I am obliged to revise my previous suggestion (KEEN, 1966, Occ. Pap. Calif. Acad. Sci. no. 59, pp. 9-10) and to admit that *Venus troglodytes* MÖRCH, 1861 is a synonym of *Tapes squamosa*. However, I feel that there are two forms on the West Coast, *Timoclea picta* (WILLETT, 1944), ranging north from Magdalena Bay and averaging more than 6 mm in length, with somewhat more subdued ribbing, and *Timoclea squamosa*, ranging from the Gulf of California southward to Peru, averaging less than 6 mm in length, with stronger scales on the concentric ribs. OLSSON has objected to the use of the generic name *Timoclea* because the type species has a nearly smooth escutcheon; perhaps we should therefore adopt the subgeneric allocation to *Glycydonta* COTTON, 1936 (based on *Venus marica* LINNAEUS, 1758), the type of which has strong scales on the posterior slope. Carpenter's largest syntype is here selected as lectotype.

## PETRICOLIDAE

47. *Rupellaria exarata*, p. 20

= *Petricola (Petricola) exarata* (CARPENTER, 1857)  
(Text figure 16)

Tablet 73, 4 syntypes. [5.3 mm]. BRANN: plt. 3, fig. 28.

Radial ribbing is somewhat developed, and the fine zigzag pattern is not as apparent as in the next species. There are a few brown color spots. One specimen was nestling in a barnacle test. COAN in 1962 (The Veliger, vol. 5, no. 2, p. 92) reported some specimens of this form taken near Mazatlan in 1961.

48. *Rupellaria linguafelis*, p. 20

= *Petricola (Petricola) linguafelis* (CARPENTER, 1857)  
(Text figure 17)

Tablet 72, 5 syntypes. [4.0 mm]. BRANN: plt. 2, fig. 27.

The specimens are juvenile, with microscopically fine zigzag striae. With growth the shell tends to become more elongate.

49. *Narario scobina*, p. 529

= *Petricola (Petricola) linguafelis* (CARPENTER, 1857)  
(Plate 55, Figures 11 a-b; Text figures 18 a-b)

Tablet 2516, holotype and hypotype. [3.3 mm]. BRANN: plt. 4, fig. 680.

When he described the species, Carpenter had but a single valve, the left valve. Later he found a larger opposite (right) valve, which he added to the mount in 1858 (CARPENTER, 1865 b, p. 269). His drawing, which therefore must have been made after 1858, shows both specimens, the hinge of the left (holotype), and the full interior of the right (hypotype). There seems no good basis for separation of the form as distinct.

## TELLINIDAE

50. *Tellina donacilla*, p. 34

?= *Tellina (Moerella) donacilla* CARPENTER, 1857  
(Text figure 19)

Tablet 116, holotype, 1 valve. [3.5 mm]. BRANN: plt. 6, fig. 53.

The shell looks like a young *Tellina amianta* DALL, 1900, but the posterior end is shorter and the lateral tooth stronger; no trace of the pallial line could be made out.

## DONACIDAE

51. *Donax ?punctatostriatus caelatus*, p. 46

= *Donax punctatostriatus* HANLEY, 1843  
(Plate 56, Figure 34)

Tablet 168, 3 syntypes; 168\*, two syntypes. [35 mm].

This form does not seem separable from Hanley's species.

52. *Donax culminatus*, p. 43

= *Donax carinatus* HANLEY, 1843  
(Plate 56, Figures 33 a-b)

Tablet 139, 2 syntypes, the smaller, from Mazatlan, here selected as lectotype. [24 mm].

Carpenter considered this a variant of *Donax carinatus* because the ridge setting off the posterior slope seemed sharper and the radial striae seemed more crowded and granular; later authors have not considered these as valid distinguishing characters.

## GARIDAE

53. *Solecortus politus*, p. 27

= *Tagelus (Mesopleura) politus* (CARPENTER, 1857)  
(Plate 56, Figure 27)

Tablet 90, 1 syntype. [37 mm].

Authors seem to have identified the species correctly. The right valve is now broken; Carpenter implied that the shell had been complete.

54. *Solecortus violascens*, p. 27, footnote

= *Tagelus (Tagelus) violascens* (CARPENTER, 1857)  
(Plate 56, Figure 37)

Tablet 90, holotype. [83 mm]. BRANN: plt. 17, lower right.

The original specimen was from the Cuming collection with an indefinite locality, "Southwest Mexico." All that remains now is a somewhat broken right valve. Fortunately, growth lines are well developed and enable the reconstruction of the correct outline. The pallial sinus reaches only just slightly past the intersection of a line drawn vertically through the beaks; Carpenter's drawing shows it not quite reaching this line. The pallial sinus in *Tagelus californianus* (CONRAD, 1837) is still shorter and the shell proportionately longer. The interior of the right valve of Carpenter's specimen was figured by PALMER (1963, plt. 64, fig.1), registry no. 1857.6.4.2531.

#### SEMELIDAE

##### 55. *Montacuta subquadrata*, p. 113

= *Semelina subquadrata* (CARPENTER, 1857)

(Text figure 11)

Tablet 503, 2 syntypes, one broken. [3.5 mm]. BRANN: plt. 10, fig. 162.

The shell is worn, with a chipped edge; the sculpture is strongly concentric; interior markings (pallial line and muscle scars) not being visible, Carpenter was unaware of the deep pallial sinus that is evident in fresh material. OLSSON (1961, p. 375; plt. 66, fig. 11) has figured the exterior sculpture and has discussed morphology and distribution.

##### 56 a. *Tellina lamellata*, p. 37

= *Semele* sp., juvenile

(Text figure 20)

Tablet 121, 3 valves. [3.3 mm].

The figure in KEEN (1958, fig. 388) is fairly correct as to outline except that Carpenter's syntypes are longer anteriorly. The hinge shows the internal ligament that is characteristic of *Semele*. The shell is probably too young for a positive determination of what *Semele* is represented. Studies of growth series might give clues.

##### 56 b. *Tellina regularis*, p. 36

= *Semele* sp., juvenile

(Text figure 21)

Tablet 120, 2 syntypes, one a fragment. [1.8 mm]. BRANN: plt. 7, fig. 57.

This resembles the "*T.*" *lamellata* in hinge and outline but has only fine concentric lines. My drawing indicates a larger size than Carpenter's cited dimensions.

##### 57. *Sphaenia fragilis*, p. 24, "n.s."

= *Sphenia fragilis* (H. & A. ADAMS, 1854)

(Text figure 22)

Tablets 80 - 82, about 15 syntypes. [8 mm]. BRANN: plt. 6, fig. 35.

The several syntypes show variations in size and outline. Authors have correctly identified the form. Unfortunately, Carpenter chose the same specific name as had H. and A. ADAMS (Genera of Shells, vol. 2, p. 368; plt.

### Explanation of Text figures 23 to 50

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 23: *Dentalium liratum*. Lectotype. Length, 7 mm (x 8).

Figure 24: *Dentalium corrugatum*. Holotype. Length, 1.5 mm (x 19).

Figure 25: *Rimula mazatlanica*. Syntype. Length, 4 mm (x 8).

Figure 26: *Scissurella rimuloides*. Holotype. Diameter, 0.9 mm (x 22). a) apertural view; b) and c) apical and lateral views, sketches, not to scale.

Figure 27: *Liotia carinata*. Holotype. Diameter, 1.6 mm (x 19).

Figure 28: *Liotia striulata*. Holotype. Diameter, 1.1 mm (x 21).

Figure 29: "*Phasianella perforata* PHILIPPI." Paralectotype of *Tricolia mazatlanica* (STRONG, 1928). Diameter, 2.6 mm (x 9).

Figure 30: *Phasianella perforata striulata*. Syntype. Diameter, 1.8 mm (x 15).

Figure 31: *Lunatia tenuilirata*. Syntype. Diameter, 1.6 mm (x 14).

Figure 32: *Leiostraca linearis*. Holotype. Length, 2.2 mm (x 14).

Figure 33: *Leiostraca producta*. Holotype. Length, 3.8 mm (x 10).

Figure 34: *Leiostraca iota retecta*. Syntype. Length, 2.6 mm (x 12).

Figure 35: *Leiostraca distorta yod*. Syntype. Length, 2.6 mm (x 12).

Figure 36: *Mucronalia involuta*. Holotype. Length, 3.2 mm (x 10).

Figure 37: *Aclis tumens*. Holotype. Length, 1.6 mm (x 19).

Figure 38: *Scalaria raricostata*. Holotype. Length, 3.5 mm (x 10).

Figure 39: *Scalaria supracriata*. Syntype. Length, 1.2 mm (x 28).

Figure 40: *Cirsotrema funiculata*. Syntype. Length, 14.5 mm (x 2.6).

Figure 41: *Vitrinella orbis*. Holotype. Diameter, 1 mm (x 23).

Figure 42: *Vitrinella bifrontia*. Syntype. a) apertural view; b) base. Diameter, 1 mm (x 23).

Figure 43: *Vitrinella coronata*. Syntype. Diameter, 1 mm (x 23).

Figure 44: *Vitrinella lirulata*. Holotype. Diameter, 2 mm (x 16).

Figure 45: *Vitrinella perparva nodosa*. Holotype. Diameter, 1 mm (x 20).

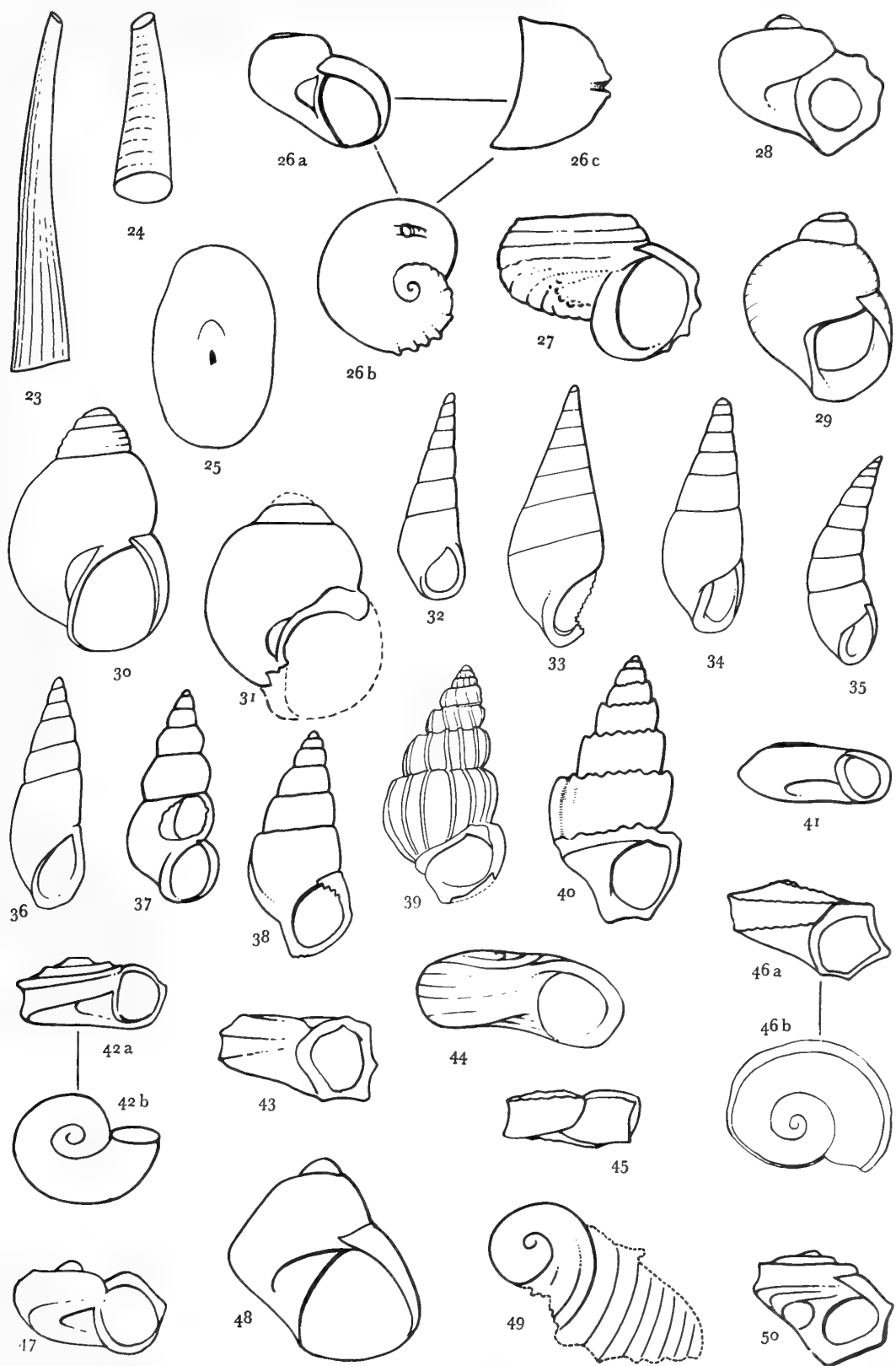
Figure 46: *Vitrinella ornata*. Holotype. a) apertural view; b) base. Diameter, 1 mm (x 23).

Figure 47: *Vitrinella tenuisculpta*. Holotype. Diameter, 1 mm (x 23).

Figure 48: *Vanicoro cryptophila*. Lectotype. Diameter, 2 mm (x 15).

Figure 49: *Vitrinella planospirata*. Holotype (fragment). Radius 3.2 mm (x 11).

Figure 50: *Vitrinella cincta*. Holotype. Diameter, 1 mm (x 20).



97, figs. 3, 3a) for their *Tyleria fragilis*. Carpenter had been skeptical of their figure and was at pains to study their type specimen, as he had seen *Sphenias* with somewhat similar features. He concluded (p. 527) that the form was correctly illustrated and was unique. I concur that the figure is accurate, but I feel certain that their specimen is pathologic. For some reason, shell material was either not deposited or was resorbed, leaving a few islands of solid calcium carbonate embedded in what is mostly periostracum. In shape, size, and hinge, the shell is strikingly similar to Carpenter's syntypes, as I could prove by comparing the two lots side by side. If my interpretation is correct, the generic name *Tyleria* falls as a synonym of *Sphenia*, and the specific name has priority from the Adamsses, 1854.

## CORBULIDAE

58. *Corbula pustulosa*, p. 22

= *Corbula nasuta* SOWERBY, 1833

(Plate 56, Figure 25)

Tablet 77, 1 syntype (here selected as lectotype). [4 mm]. BRANN: plt. 4, fig. 32.

The lectotype shows clearly the radial rows of small pustules that are the hallmark of juvenile *Corbula nasuta*. Carpenter's other syntype was from the Cuming collection, from "Panama and San Blas."

## PHOLADIDAE

59. *Martesia intercalata*, p. 13

= *Penitella conradi* VALENCIENNES, 1846

Tablet 41 (sketches).

The type material consisted of two specimens in the Hanley collection, of which Carpenter made drawings. The shells are no longer available. Ruth Turner has reproduced the drawings (*Johnsonia*, vol. 3, no. 34, p. 75, plt. 72, figs. 1-2, 1955).

## SCAPHOPODA

## DENTALIIDAE

60. *Dentalium liratum*, p. 188

= *Dentalium semipolatum* BRODERIP & SOWERBY, 1829

(Text figure 23)

Tablet 879. [6 mm]. BRANN: plt. 19, fig. 244.

Carpenter cited a "perfect specimen" (here selected as lectotype), a small specimen, and a fragment. There are two juvenile shells on the tablet, one of which is probably a caecid. PILSBRY & SHARP (*Manual of Conchology*, vol. 17, p. 92, 1897) suggested the synonymy here accepted.

## Explanation of Plate 56

All specimens are in the British Museum (Natural History), Mollusca Section. They were photographed in place on glass mounts.

Generic and specific names are as cited by CARPENTER.

Figure 21: *Lucina pectinata*. Holotype, left valve. Length, 13 mm (x 3).

Figure 22: *Lucina prolongata*. Four unmatched syntype valves. a, d) interior, left valve; b) interior, right valve; c) exterior, left valve. Length, 3 mm to 3.5 mm (x 3).

Figure 23: *Lucina excavata*. Syntype, exterior, seen through glass mount (the central circular area is glue). Length 10 mm (x 3.5).

Figure 24: *Lasea oblonga*. Holotype, left valve, interior. Length, 5.7 mm (x 4.5).

Figure 25: *Corbula pustulosa*. Exterior, left valve, lectotype (here selected). Length, 4.2 mm (x 4.5).

Figure 26: *Diplodonta subquadrata*. Syntype. a) interior, left valve; b) exterior, right valve. Length 26.3 mm (x 1.3).

Figure 27: *Solecurtus politus*. Syntype, left valve. a) exterior; b) interior. Length, 32 mm (x 1).

Figure 28: *Lasea trigonalis*. a) interior, left valve; b) interior, right valve, lectotype (here selected). Length, 7.5 mm (x 3). c) exterior of paralectotype, seen through glass mount (central shiny area is glue). Length, 7.6 mm (x 4.6).

Figure 29: *Lucina mazatlanica*. Two syntypes. a) interior, right

valve. Length, 3.2 mm; b) interior, left valve. Length 2 mm (x 10).

Figure 30: *Diplodonta discrepans*. Holotype. a) exterior, right valve; b) interior, right valve; c) exterior, left valve; d) interior, left valve. Length, 8 mm (x 3).

Figures 31, 35: *Chama frondosa fornicata*. Syntypes, sub-adults. 31 a) interior, left valve; 31 b) exterior, right valve; maximum length, 78 mm (x 0.6); 35a) interior, left valve; 35b) interior, right valve; maximum length, 45 mm (x 1).

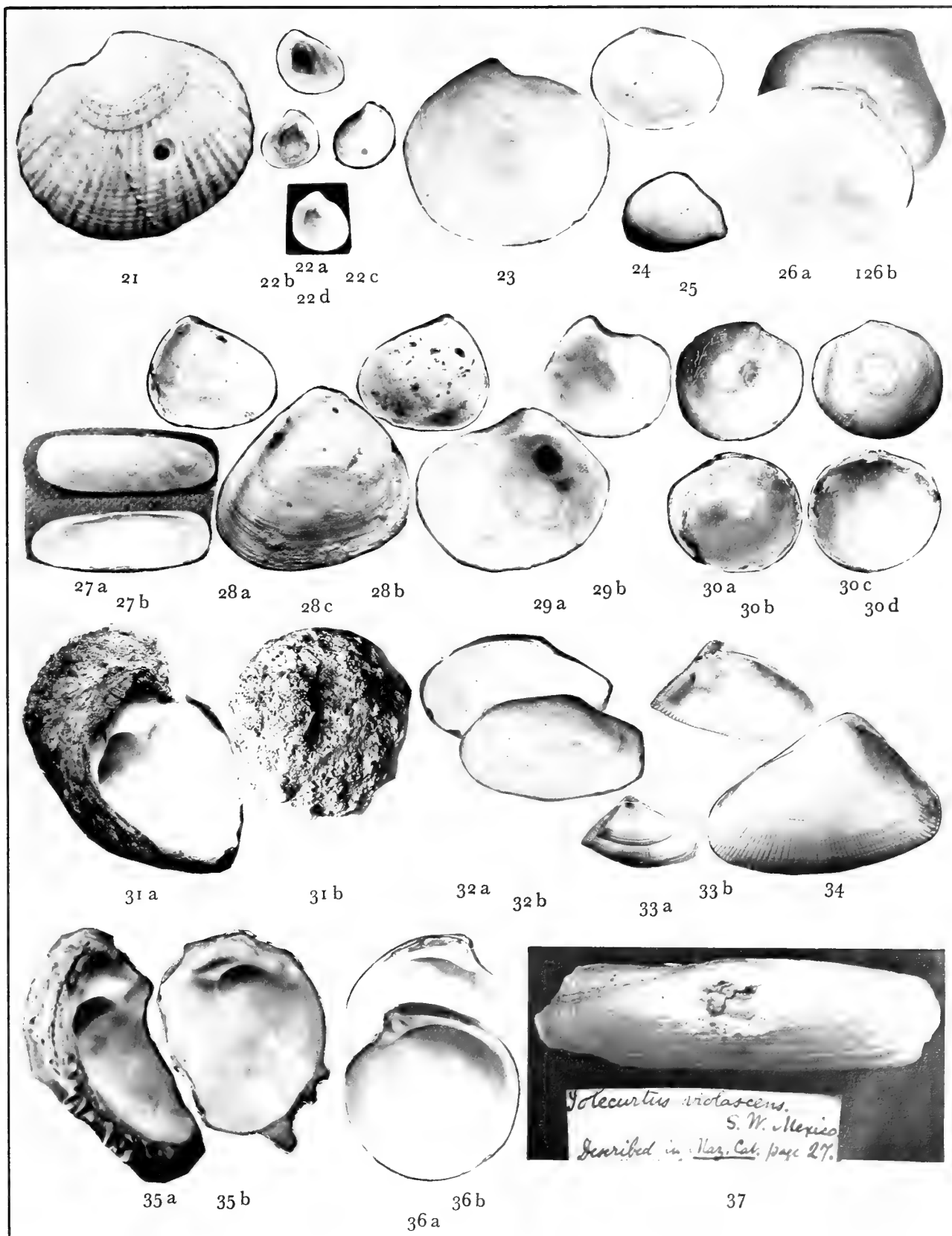
Figure 32: *Thracia squamosa*. Holotype, Cuming collection. a) interior, right valve; b) exterior, left valve. Length, 28 mm (x 1.1).

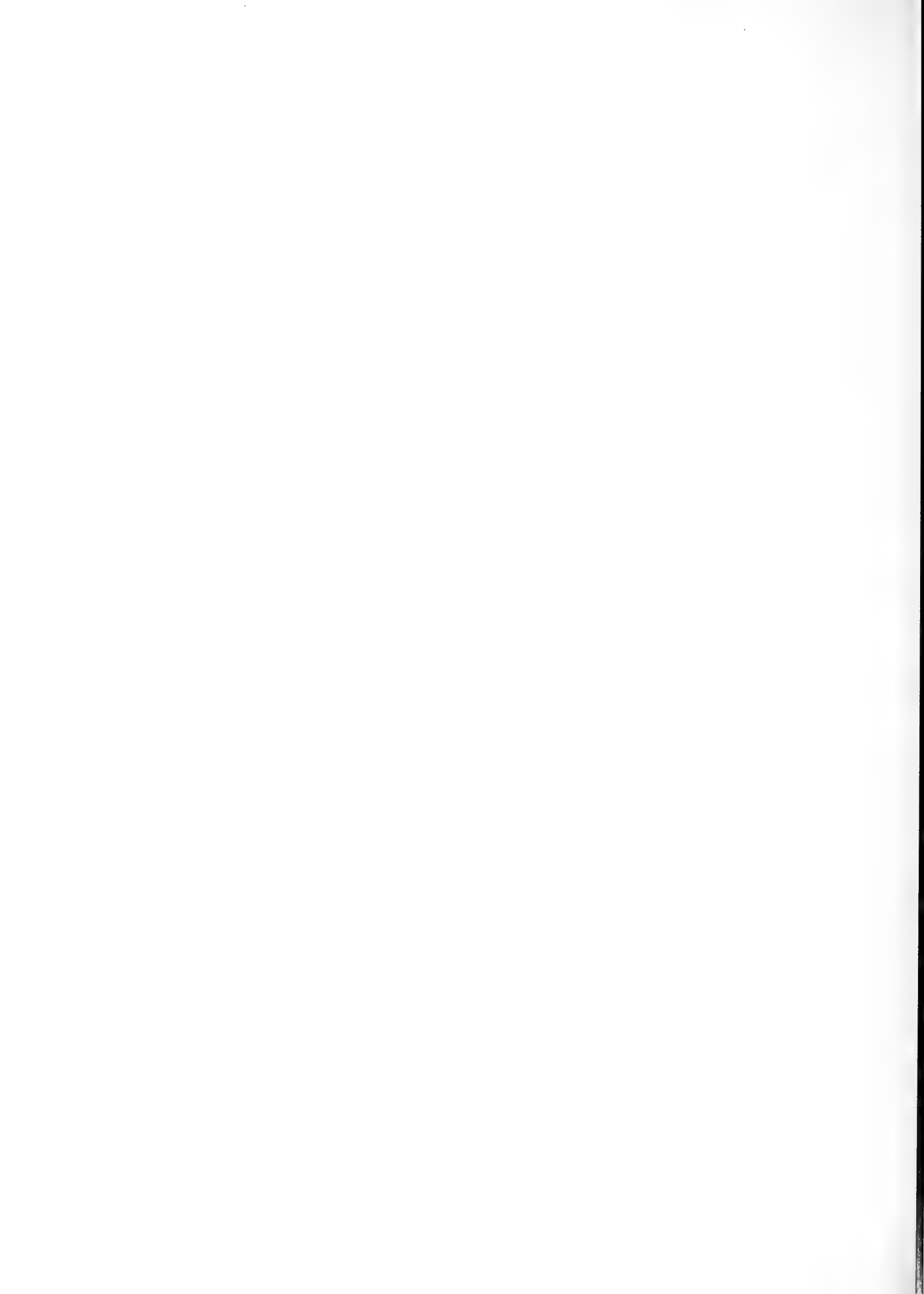
Figure 33: *Donax culminatus*. Lectotype (here selected), exterior, right valve. Length, 25 mm (x 0.8). b) Hypotype, interior, left valve of a pair from an unknown Central American locality. Length, 37 mm (x 0.8).

Figure 34: *Donax caelatus*. Exterior, left valve of a syntype, largest of three specimens. Length, 37 mm (x 1.1).

Figure 36: *Dosinia annae*. Lectotype (here selected). a) interior, right valve; b) interior, left valve. Length, 60 mm (x 0.5).

Figure 37: *Solecurtus violascens*. Holotype, with Carpenter's label, from "Southwest Mexico." Length, 83 mm (x 0.9).





61. *Dentalium corrugatum* CARPENTER, 1857, p. 189  
(non HUPÉ in GAY, 1854)  
= *Dentalium semipolitum* BRODERIP & SOWERBY, 1829  
(Text figure 24)

Tablet 881, holotype. [1.2 mm]. BRANN: plt. 19, fig. 246.

The shell is probably too young for positive determination, but as the name is preoccupied, synonymizing seems the best course.

62. *Dentalium ?pretiosum* "Nutt. (teste Hinds)," p. 189  
nomen nudum

Tablet 882.

The citation is based on a specimen too worn and broken for determination. Had Carpenter validated the name by giving a description, it would have taken precedence over Sowerby's usage of 1860.

## GASTROPODA

### FISSURELLIDAE

63. *Fissurella alba*, p. 218 (non PHILIPPI, 1845)  
= *Fissurella gemmata* MENKE, 1847  
(Plate 57, Figures 38 a-b)

Tablets 1058 - 1068, 29 syntypes (tablet 1059 photographed). [41 mm].

Carpenter had some misgivings about the identity of MENKE's species, but later authors have generally accepted the synonymy. Menke's type material, however, has not been studied.

64. *Fissurella nigrocincta* CARPENTER, 1856a, p. 234  
(cited 1857b, p. 217, as "n.s.")  
= *Fissurella nigrocincta* CARPENTER, 1856  
(Plate 57, Figures 39 a-b)

Tablet 1056, 2 juvenile syntypes. [19 mm]. BRANN: plt. 19, fig. 274.

The species was described from adult material in the Cuming collection, locality not stated, shown in my photograph. Carpenter cited the locality in 1857 as Mazatlan, but the label says "California." The figure in BRANN is of a juvenile shell on tablet 1056, which Carpenter referred to this species with some doubt. Sowerby published an illustration of the adult in 1862 (Thesaurus Conch., vol. 3, plt. 239, figs. 61 - 63).

65. *Fissurella spongiosa*, p. 219  
= *Fissurella nigrocincta* CARPENTER, 1856  
(Plate 57, Figures 40 a-b)

Tablet 1070, syntype, here selected as lectotype. [18 mm].

The shell is immature and worn, which accounts for the texture.

66. *Rimula mazatlanica*, p. 222  
= *Diodora* sp., juvenile  
(Text figure 25)

Tablet 1080, 3 syntypes. [3.1 mm]. BRANN: plt. 22, fig. 281.

The species has also been figured by Sowerby in Reeve (Conch. Icon., vol. 19, plt. 1, sp. 5, 1873). The callus on the inside of the apex has the truncation of *Diodora*, and there are a few color spots on the shell; also, the sculpture near the margin is like that of *Diodora*. As BERRY (1964, Leaflets in Malacology, no. 24, p. 148) has surmised, this form represents the growth stage in which the orifice has not yet absorbed the pointed apex.

### SCISSURELLIDAE

67. *Scissurella rimuloides* CARPENTER, 1865 b, p. 271  
= *Sinezona rimuloides* (CARPENTER, 1865)  
(Text figures 26 a - c)

Tablet 2532, holotype. [0.7 mm]. BRANN: plt. 22, fig. 698.

The species seems to have been correctly identified by authors.

### TROCHIDAE

68. *Trochus macandreae*, p. 232  
= *Calliostoma macandreae* (CARPENTER, 1857)  
(Plate 57, Figure 41)

Tablet 1129, 1 syntype and some fragments. [8.7 mm].

The photographed specimen is here selected as lectotype. A specimen from the Cuming collection was figured by Reeve, 1863 (Conch. Icon., vol. 14, plt. 7, figs. 50-51), as *Ziziphinus macandreae*.

69. *Omphalius globulus*, p. 236  
= *Tegula (Agathistoma) globulus* (CARPENTER, 1857)  
(Plate 57, Figures 52 a-b)

Tablet 1145, 1 syntype, here selected as lectotype. [8.4 mm].

There have been some differences of opinion among collectors as to the identity of this form.

70. *Omphalius ?rugosus* var. *rufotinctus*, p. 233  
= *Tegula (Omphalius) rugosa* (A. ADAMS, 1853)  
(Plate 57, Figures 45 a-b)

Tablets 1130 - 1131, 3 syntypes. [30 mm]

The 3 syntypes of *Chlorostoma rugosum* A. ADAMS, 1853 are also in the type collection of the British Museum, with the locality "China." Because of this incorrect

and indefinite label, Carpenter described the Mazatlan form as a new variety. I regard the two lots as conspecific and consider Adam's locality to be in error.

#### LIOTIIDAE

##### 71. *Liotia carinata*, p. 248

= *Arene carinata* (CARPENTER, 1857)

(Text figure 27)

Tablet 1164, holotype. [1.1 mm]. BRANN: plt. 25, fig. 313

As Carpenter noted, the shell is immature, but the sculpture is well developed. The spire is so depressed that it does not show in the apertural view of the shell. STRONG (1934, Trans. San. Diego Soc. Nat. Hist., vol. 7, no. 37, p. 440; plt. 28, figs. 1-3) was probably not justified in using a figure of the holotype of *Liotia lurida* DALL, 1913 under the name of *L. carinata*. His figure of another specimen (*ibid.*, plt. 31, figs. 1-3) is of a shell with a tabulate but not flattened spire. Dall's species should be reinstated as distinct. Carpenter's form has not been recorded again unequivocally, but some specimens in the Stanford University collection from the La Paz area approach his figure in flatness of spire.

##### 72. *Liotia striulata*, p. 248

= *Arene striulata* (CARPENTER, 1857)

(Text figure 28)

Tablet 1165, holotype. [0.7 mm] BRANN: plt. 26, fig. 314.

Carpenter's shell has an unusually thick apertural margin. The spire is higher than in *Arene carinata*. His drawing is somewhat tilted, and he exaggerated the spi-

ral sculpture. Part of the lip thickening seems to be a build-up of the mounting glue. One specimen in the Stanford University collection, dredged off La Paz, matches the figure fairly well as to size and shape, but it has a thinner apertural margin and does not have the sculpture so markedly developed.

##### 73. *Liotia c-b-adamsii*, p. 248

Tablet 1166, holotype. [0.6 mm]. BRANN: plt. 26, fig. 315.

The holotype is now completely disintegrated by chemical alteration. Carpenter's drawing suggests the apical whorls of a juvenile shell that evidently is not liotiid. For all practical purposes it must be regarded as a *species dubia*. In a way this may be well, because under the new International Rules of Zoological Nomenclature, the name must be written without hyphens, which results in an unpronounceable vocable, *cbadamsii*.

#### PHASIANELLIDAE

##### 74. "*Phasianella perforata* PHILIPPI," p. 224 (not of PHILIPPI, 1845)

= *Tricolia mazatlanica* (STRONG, 1928), "new name"

(Plate 57, Figure 46; Text figure 29)

Tablet 1084, 5 syntypes. [3.3 mm]. BRANN: pl. 22, fig. 283.

The type of Philippi's species was from Peru. STRONG (1928, p. 198) reprinted Carpenter's description and cited a figure in REEVE (Conch. Icon., vol. 13; plt. 6, fig. 17, 1862), of a specimen in the Cuming collection from Mazatlan and Panama. A specimen with an operculum, mentioned by Carpenter, is now the only good specimen of the Reigen lot, and it is here selected as lectotype of Strong's species.

### Explanation of Text figures 51 to 74

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 51: *Vitrinella decussata*. Syntype. Diameter, 1.3 mm (x 16).

Figure 52: *Vitrinella monile*. Syntype. Diameter, 1.6 mm (x 17).

Figure 53: *Vitrinella monilifera*. Syntype. Diameter, 1.2 mm (x 20).

Figure 54: *Vitrinella annulata*. Holotype. Diameter, 1.6 mm (x 17).

Figure 55: *Ethalia carinata*. Syntype. Diameter, 1 mm (x 19).

Figure 56: *Vitrinella carinulata*. Holotype. Diameter, 1 mm (x 16).

Figure 57: *Ethalia pyrallosa*. Holotype. Diameter, 1.4 mm; a) apertural view (x 23); b) base (x 18).

Figure 58: *Teinostoma amplectans*. Holotype. Diameter, 3.3 mm (x 9).

Figure 59: *Globulus amplectans*. Syntype. Diameter, 1 mm; a) apertural view (x 23); b) base (x 27).

Figure 60: *Globulus lirulata*. Syntype. a) apertural view; b) basal view. Diameter, 1 mm (x 23).

Figure 61: *Globulus pallidula*. Holotype. Diameter 1 mm (x 25).

Figure 74: *Rissoa lirata*. Syntype. Length, 4 mm (x 8).

Figure 62: *Teinostoma substriatum*. Syntype. Diameter, 1.2 mm; a) apertural view, (x 19); b) basal view (x 20).

Figure 63: *Globulus sulcatus*. Syntype. Diameter, 1 mm (x 28).

Figure 64: *Globulus tumens*. Syntype. a) apertural view; b) basal view. Diameter, 1.6 mm (x 15).

Figure 65: *Vitrinella biflata*. Syntype. Diameter, 1.5 mm (x 19).

Figure 66: *Vitrinella naticoides*. Syntype. Diameter, 1.2 mm (x 20).

Figure 67: *Vitrinella subquadrata*. Syntype. Diameter, 1.2 mm (x 19).

Figure 68: *Alvania tumida*. Syntype. Diameter, 1.6 mm (x 10).

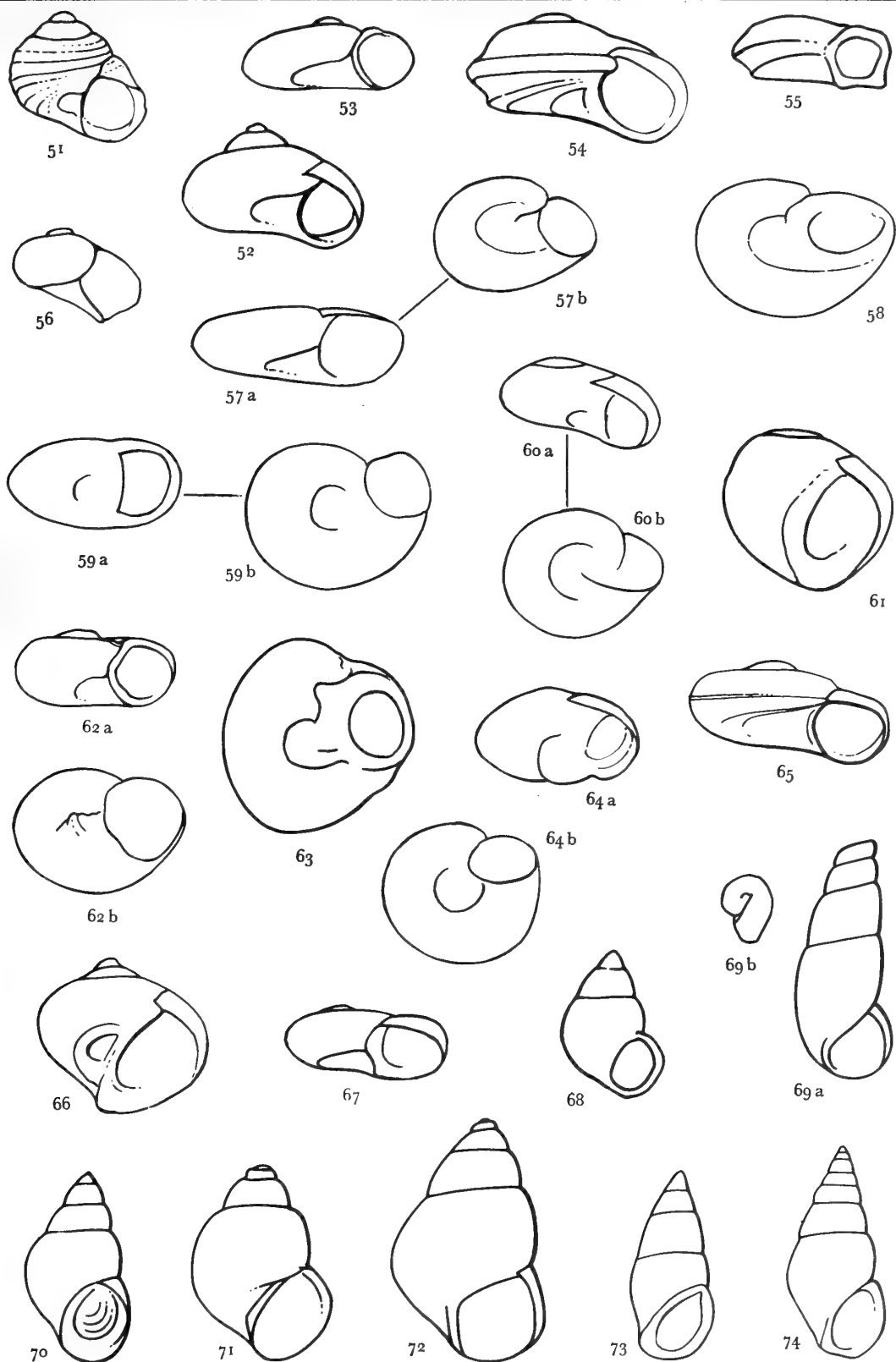
Figure 69: *Aclis fusiformis*. Syntype. Length, 1.8 mm; a) apertural view; b) detail of initial apical whorl from back of shell (x 18).

Figure 70: *Jeffreysia bifasciata*. Syntype. Length, 1.6 mm (x 17).

Figure 71: *Jeffreysia tumens*. Syntype. Length, 1.6 mm (x 17).

Figure 72: *Jeffreysia alderi*. Syntype. Length, 2 mm (x 18).

Figure 73: *Rissoina woodwardii*. Syntype. Length, 3.6 mm (x 8).



75. *Phasianella* ?*perforata*, var. *striulata*, p. 225  
= *Tricolia striulata* (CARPENTER, 1857)  
(Text figure 30)

Tablet 1085, 1 syntype, registry no. 1857.6.4.1085. [2.2 mm]. BRANN: plt. 22, fig. 283b.

STRONG (1928, p. 198), in proposing the name *Phasianella mazatlanica* as a replacement for Carpenter's misidentification, seems to have overlooked Carpenter's varietal name. If, as seems possible, this form is not separable from the one on tablet 1084 (the only cited difference being less apparent sculpture), then Strong's *T. mazatlanica* will fall into synonymy, having been junior to *T. striulata* less than 50 years required for the latter to become a *nomen oblitum*.

76. *Phasianella compta* "GOULD MSS," p. 225  
? *Phasianella*, s. l., sp.

Tablet 1086. BRANN: plt. 22, fig. 284.

It is probable that Carpenter's Mazatlan specimen is misidentified, for *Tricolia compta* (GOULD, 1855) is a Californian form. A note with the specimen, by Dr. R. Robertson, 1962, suggests that this is a ballast shell from the Indo-Pacific or Caribbean and is unidentifiable.

77. *Lunatia tenuilirata*, p. 451  
= *Tricolia tenuilirata* (CARPENTER, 1857)  
(Text figure 31)

Tablet 2052, syntype. [1.4 mm]. BRANN: plt. 50, fig. 572.

Carpenter mentions two specimens, a broken older and a perfect young shell and says the mount contains the latter. However, the one on the tablet has an incomplete aperture and the dimensions are closer to those he cites for the larger specimen. This form seems very close to *Tricolia substriata* (CARPENTER, 1864), from the Californian area, and only minor differences can be seen between a photograph of a Californian shell (STRONG, 1928, p. 195; plt. 10, fig. 11) and the camera lucida drawings by Carpenter and myself. Possibly the record of *T. substriata* at San José Island, Gulf of California, cited by STRONG, should be considered as of *T. tenuilirata* instead. The main differences seem to be that the Mazatlan syntype has stronger developed color banding of white spots (not shown in Carpenter's drawing) and a heavier inner lip on the aperture.

#### PHENACOLEPADIDAE

78. *Scutellina navicelloides*, p. 211  
= *Phenacolepas osculans* (C. B. ADAMS, 1852)  
(Plate 57, Figures 44 a-b)

Tablet 1016, holotype. [5.6 mm]. BRANN: plt. 21, fig. 269.

The apex of the holotype is broken away. Outline, however, and sculpture seem to confirm synonymy with Adams' species.

### Explanation of Plate 57

All specimens are in the British Museum (Natural History), Mollusca Section. They were photographed in place on glass mounts.

Generic and specific names are as cited by CARPENTER.

Figure 38: *Fissurella alba*. a) interior; b) exterior; two syntypes. Length of larger, 36 mm (x 1).

Figure 39: *Fissurella nigrocincta*. Two of 3 syntypes, Cuming collection. a) exterior; b) interior. Length of largest specimen in lot, 18 mm (x 1.5).

Figure 40: *Fissurella spongiosa*. Lectotype (here selected). a) exterior, seen through glass; b) interior. Length, 17 mm; a) (x 2.2); b) (x 1.1).

Figure 41: *Trochus macandreae*. Lectotype (here selected). Diameter, 9 mm (x 4).

Figure 42: *Hipponyx planatus*. Two syntypes, Cuming collection, from Panama. a) interior, b) exterior of specimen on which from Panama. a) interior; b) exterior of specimen on which Carpenter cited dimensions. Length, 18 mm (x 1.3).

Figure 43: *Hipponyx serratus*. Two syntypes. a) exterior; b) interior. Diameter (larger syntype). 23 mm (x 1).

Figure 44: *Scutellina navicelloides*. Holotype. a) interior (x 3.3); b) exterior, seen through glass mount (central area that appears flattened is the mounting glue) (x 5.2). Length, 5.5 mm.

Figure 45: *Omphalius rufotinctus*. Two syntypes. a) diameter, 18 mm; b) diameter, 24 mm (x 1).

Figure 46: "*Phasianella perforata* PHILIPPI." Lectotype (here selected) of *P. mazatlanica* STRONG, 1928. Height, 2.5 mm (x 8).

Figure 47: *Cerithidea mazatlanica*. Four syntypes. Length of largest, 28 mm (x 1).

Figure 48: *Cerithium alboliratum*. Lectotype (here selected). Height, 4.0 mm (x 7).

Figure 49: *Scalaria varicostata*. Holotype. Length, 3.3 mm (x 13).

Figure 50: *Cirsotrema funiculata*. a) Lectotype (here selected), largest of 3 specimens from Panama, Cuming collection. Length, 21 mm (x 1.9). b) Hypolectotype, from Mazatlan. Length, 16 mm (x 2.4).

Figure 51: *Cerithium mediolaeva*. Holotype. Length, 25.3 mm (x 1.7).

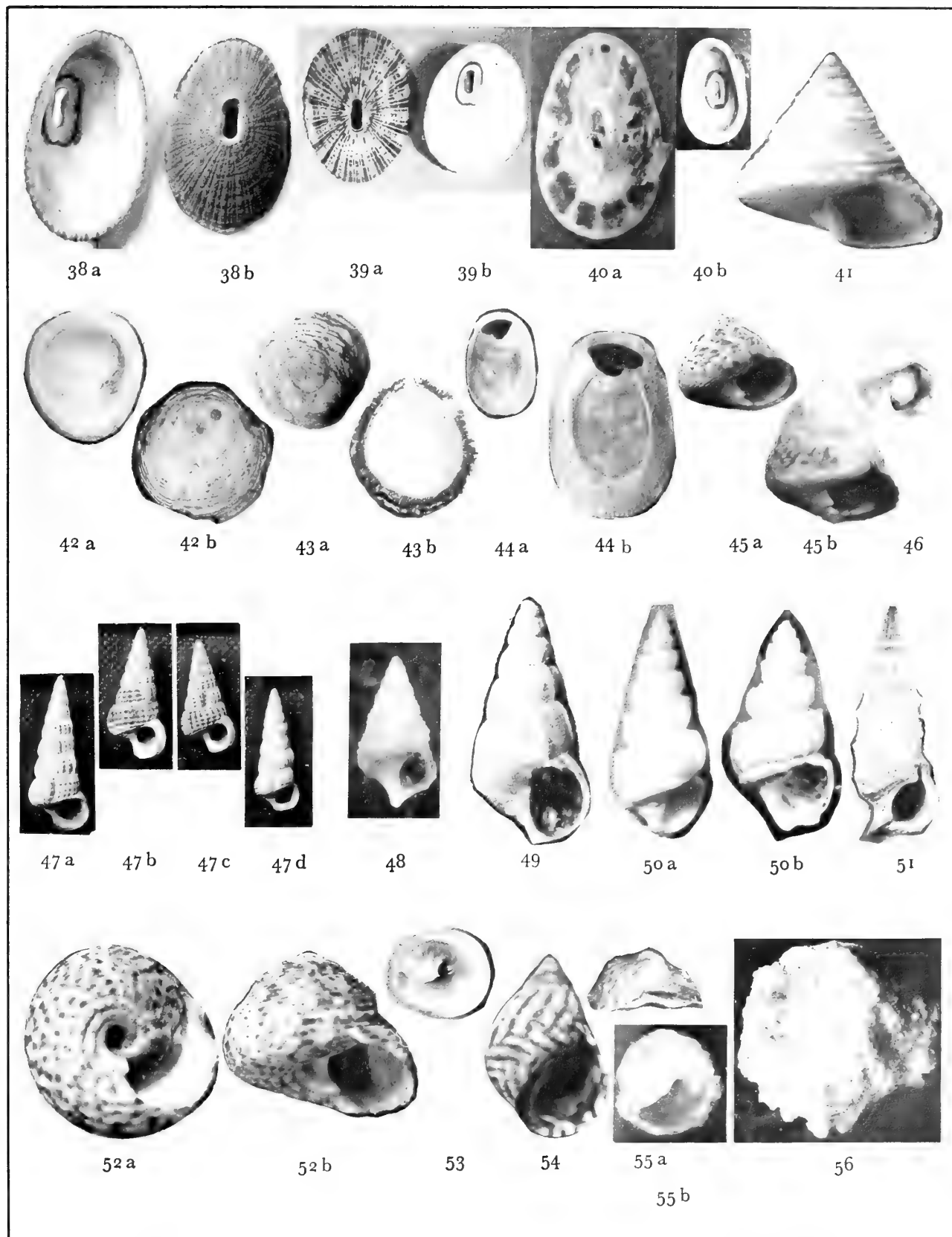
Figure 52: *Omphalius globulus*. Lectotype (here selected). a) basal view; b) apertural view. Diameter, 8.5 mm (x 4).

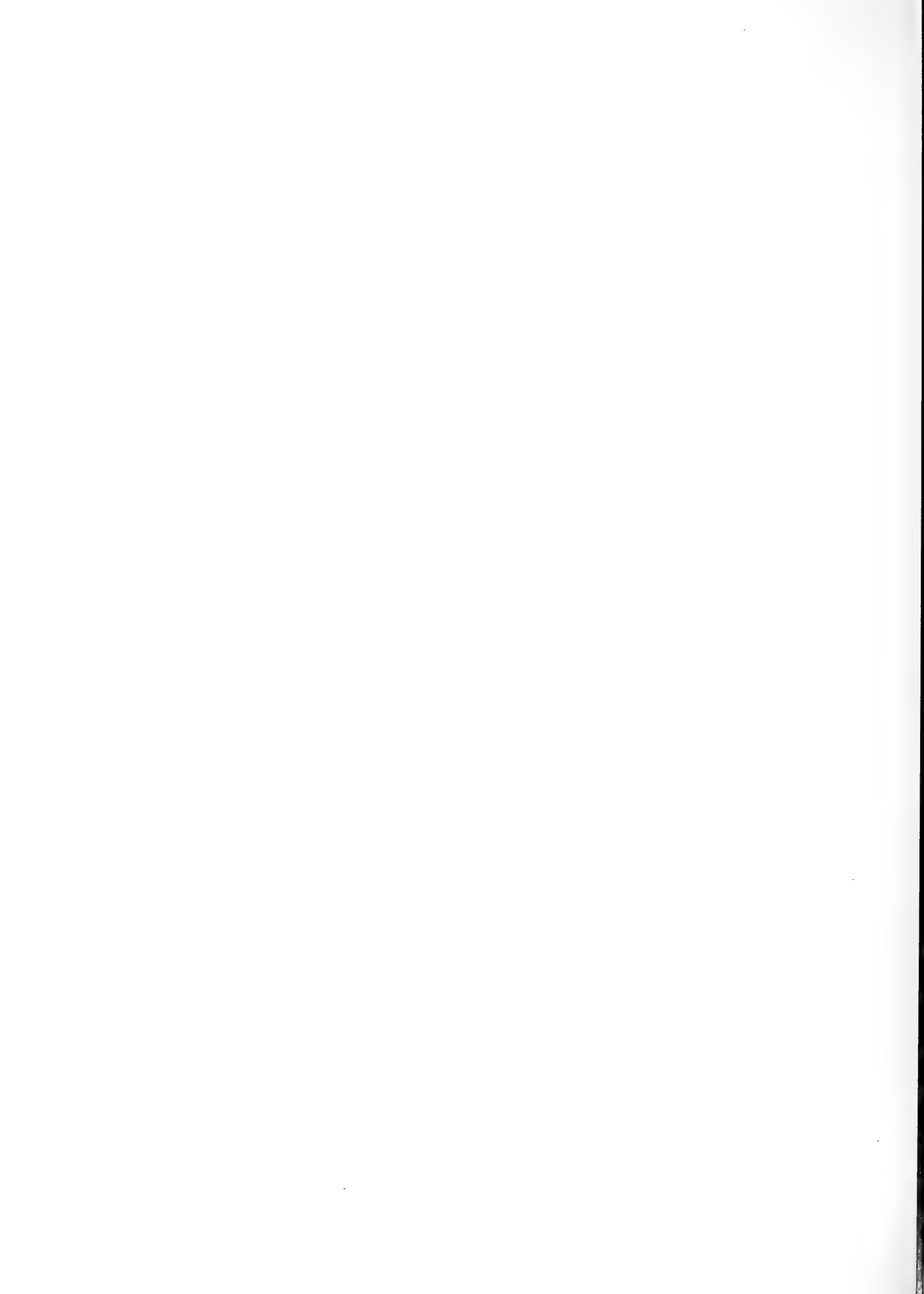
Figure 53: *Galerus fuscus*. Holotype, from "Gulf of California." Diameter, 15.5 mm (x 1.1).

Figure 54: *Litorina philippii*. Syntype. Length, 11 mm (x 3).

Figure 55: *Trochita ventricosa*. Holotype. a) side view; b) basal view. Diameter, 19 mm (x 1).

Figure 56: *Crepidula bilobata*. Exterior of a syntype. Diameter 9 mm (x 4).





## EULIMIDAE

79. *Leiostraca linearis*, p. 440

= *Balcis linearis* (CARPENTER, 1857)  
(Text figure 32)

Tablet 2025, holotype. [1.8 mm]. BRANN: plt. 48, fig. 554.

BARTSCH (1917, p. 310; plt. 36, fig. 4) did not reproduce the original figure, as he did with other of Carpenter's Mazatlan forms, but figured instead a specimen from off Baja California. His identification seems to be correct.

80. *Leiostraca producta* CARPENTER, 1864

= *Balcis producta* (CARPENTER, 1864)  
(Text figure 33)

Tablet 2022, holotype. [3.1 mm]. BRANN: plt. 48, fig. 551.

Although he did not publish a formal description until 1865, Carpenter introduced the name earlier with an acceptable indication (1864 a, p. 357), in connection with discussions of the C. B. Adams types, when he decided that his identification of Mazatlan material with a Panama form had been unjustified. Carpenter's drawing seems distorted. Having made a separate one of my own from the type, I cannot reconcile the two unless he rotated the shell on account of the broken outer lip and attempted a restoration. The body whorl seems wider than in any other Panamic *Balcis* in proportion to the height of the spire.

81. *Leiostraca ?iota* var. *retexta*, p. 440

= *Balcis retexta* (CARPENTER, 1857)  
(Text figure 34)

Tablet 2026, 1 syntype. [2.2 mm]. BRANN: plt. 48, fig. 555.

BARTSCH (1917, p. 317; plt. 38, fig. 1) reprinted the original discussion of Carpenter and published the camera lucida drawing now available in Brann's plates. My own drawing of the type differs in minor details but in general confirms Carpenter's accuracy.

82. *Leiostraca ?distorta*, var. *yod*, p. 441

= *Balcis yod* (CARPENTER, 1857)  
(Text figure 35)

Tablet 2027, 4 syntypes. [2.0 mm]. BRANN: plt. 48, fig. 556.

Again, BARTSCH (1917, p. 330; plt. 40, fig. 9) published a Carpenter drawing, not having recognized any specimens of this form. My own drawing of the largest syntype differs only in the rendering of the inner lip.

83. *Mucronalia involuta* CARPENTER, 1865 b, p. 273

= ?*Eulima involuta* (CARPENTER, 1865)  
(Text figure 36)

Tablet 2021, holotype. [2.7 mm]. BRANN: plt. 48, fig. 550.

In his monograph on melanellid mollusks, BARTSCH (1917, p. 297) stated that as this form has a tilted apex, it is an *Odostomia*. However, he had not cited it as such in the pyramidellid monograph (DALL & BARTSCH, 1909), at which time it was stated that he had studied Carpenter's types at the British Museum. Thus, this species was omitted in both of the accounts and had not been figured until the publication of Carpenter's plates. My observations confirm Carpenter's statement that there is no columellar fold. I could not see the apical whorls as heterostrophic. The holotype is very worn and is brown stained. Its general shape, the form of the outer lip, the lack of a columellar fold, and the apparently simple apex seem to point to eulimid rather than pyramidellid affinities.

## ACLIDIDAE

84. *Aclis tumens*, p. 438

= ?*Aclis tumens* CARPENTER, 1857  
(Text figure 37)

Tablet 2017, holotype. [1.3 mm]. BRANN: plt. 48, fig. 546.

Placement of the genus *Aclis* and the family ACLIDIDAE is unsettled. The shells resemble pyramidellids in many ways but lack a columellar fold; the apex is normal. They do not have the shiny texture of the EULIMIDAE, and the whorls tend to be more inflated. My notes on *Aclis tumens* indicate that the apex is minute, sunken but apparently dextral, the back of the shell seeming to show faint spiral sculpture but the front smooth. The holotype has a large break.

## EPITONIIDAE

85. *Scalaria varicostata*, p. 447 [non WOOD, 1828]

= *Epitonium* (?*Nitidiscala*) *carpenteri* (TAPPARONE-CANEFRI, 1876)  
(Plate 57, Figure 49; Text figure 38)

Tablet 2040, holotype. [3.1 mm]. BRANN: plt. 50, fig. 568.

The holotype has a slightly worn look and is greyish in color. Axial sculpture does not appear until the fourth apical whorl. The allocation to *Epitonium* (*Punctiscala*) in KEEN, 1958 (p. 276), following STRONG in BURCH, (Min. Conch. Club S. Calif. no. 52, p. 20, 1945) was

ill-advised, for there is no evidence of spiral punctations between the low varices, of which there are 7 per whorl.

BRANN (1966, p. 17) cites Carpenter's specific name as available because the name given by LAMARCK in 1822 that had been considered by some authors to preoccupy Carpenter's was spelled *S. raricosta*. However, WOOD in 1828 used the spelling *raricostata* for what is evidently another species in the genus.

86. *Scalaria suprastrata*, p. 446

= *Epitonium (Nitidiscala) suprastratum* (CARPENTER, 1857)

(Plate 59, Figure 101; Text figure 39)

Tablet 2037, 1 syntype. [11 mm].

Although the edges of the varices on the type (which is stored in the British Museum's Type Collection) are somewhat chipped, the shell is otherwise in good condition. The dimensions seem close to those of *Epitonium roberti* DALL, 1917.

87. *Scalaria (Cirsotrema) funiculata*, p. 447

= *Opalia diadema funiculata* (CARPENTER, 1857)

(Plate 57, Figure 50; Text figure 40)

Tablet 2041, 1 syntype, with broken aperture. [14.5 mm]. Three syntypes from Panama, Cuming collection.

In the annotated copy of his Catalogue, left at the British Museum, Carpenter had correctly reassigned this species to *Opalia*. The largest specimen of the 3 from Panama is more slender and high-spired than the other syntypes. Carpenter was not convinced of a distinction

of the species from the Ecuadorean *O. diadema* (SOWERBY, 1832). Because the largest Panama specimen is the only one differing enough in outline possibly to justify separation of the northern form, it is here selected as lectotype (Plate 57, Figure 50 a).

The ribs in this form seem more distinct than in the Californian *Opalia crenimarginata* (DALL, 1917), which it resembles.

## JANTHINIDAE

88. *Ianthina striulata*, p. 185

= *Janthina janthina* (LINNAEUS, 1758)

(Plate 59, Figure 79)

Tablets 868-876, 37 adults (tablet 872 photographed). [20 mm].

There seems no basis for separating Pacific and Atlantic forms of this pelagic species. REEVE (1858, Conch. Icon., vol. 11, plt. 2, sp. 6) cited the Carpenter name under synonymy of *Janthina fragilis* LAMARCK, 1801.

89. *Ianthina striulata*, var. *contorta*, p. 186

= *Janthina janthina* (LINNAEUS, 1758)

(Plate 59, Figure 80)

Tablet 877, 2 syntypes (only one now on the tablet). [Size not given.].

Synonymy with the Atlantic form seems justifiable. REEVE (1858, Conch. Icon., vol. 11, plt. 4, sp. 19) figured a specimen from Mazatlan said to be in the Cuming collection.

## Explanation of Text figures 75 to 104

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 75: *Caecum clathratum*. Syntype. Length, 2.9 mm (x 14).

Figure 76: *Caecum compactum*. Syntype. Length, 2.8 mm (x 15).

Figure 77: *Caecum elongatum*. Syntype. Length, 3 mm (x 10).

Figure 78: *Caecum farcimen*. Syntypes. Length, a) 1.7 mm (x 17); b) 1.6 mm (x 16).

Figure 79: *Caecum quadratum*. Syntypes. Length, a), b) 2 mm (x 16).

Figure 80: *Caecum semilaeve*. Syntype. Length, 3.2 mm (x 11).

Figure 81: *Caecum subimpressum*. Syntype. Length, 3.4 mm (x 10).

Figure 82: *Caecum undatum*. Syntype. Length, 2 mm (x 17).

Figure 83: *Caecum heptagonum*. Holotype, incomplete, side and sectional views. Diameter, 0.8 mm (x 17).

Figure 84: *Caecum liraticinctum*. Syntypes. Length, a) 4 mm (x 13); b) 3 mm (x 14).

Figure 85: *Caecum subconicum*. Syntypes. Length, a), b) 2.4 mm (x 10).

Figure 86: *Caecum subobsoletum*. Syntype. Length, 3 mm (x 14).

Figure 87: *Caecum tenuiliratum*. Holotype. Length, 2.8 mm (x 14).

Figure 88: *Caecum abnormale*. Syntype. Length, 1.6 mm (x 17).

Figure 89: *Caecum insculptum*. Syntypes. a) Length, 1.5 mm (x 10); b) Length, 4 mm (x 10).

Figure 90: *Caecum obtusum*. Syntype. Length, 3.9 mm (x 12).

Figure 91: *Caecum subspirale*. Syntype. Length, 4.6 mm (x 10).

Figure 92: *Caecum dextroversum*. Syntypes. a) Length, 2.4 mm (x 14); b) Length, 2 mm (x 15).

Figure 93: *Caecum reversum*. Holotype. Length, 1.6 mm (x 17).

Figure 94: *Caecum teres*. Syntype. Length, 3.2 mm (x 14).

Figure 95: *Caecum corrugulatum*. Holotype. Length, 2.2 mm (x 17).

Figure 96: *Bivonia albida*. Syntype. Length of coil, 10 mm (x 7).

Figure 97: *Cerithium alboliratum*. Lectotype. Length, 4 mm (x 7).

Figure 98: *Cerithiopsis albonodosa*. Syntype. Length, 1.7 mm (x 14).

Figure 99: *Cerithiopsis cerea*. Holotype. Length, 3 mm (x 12).

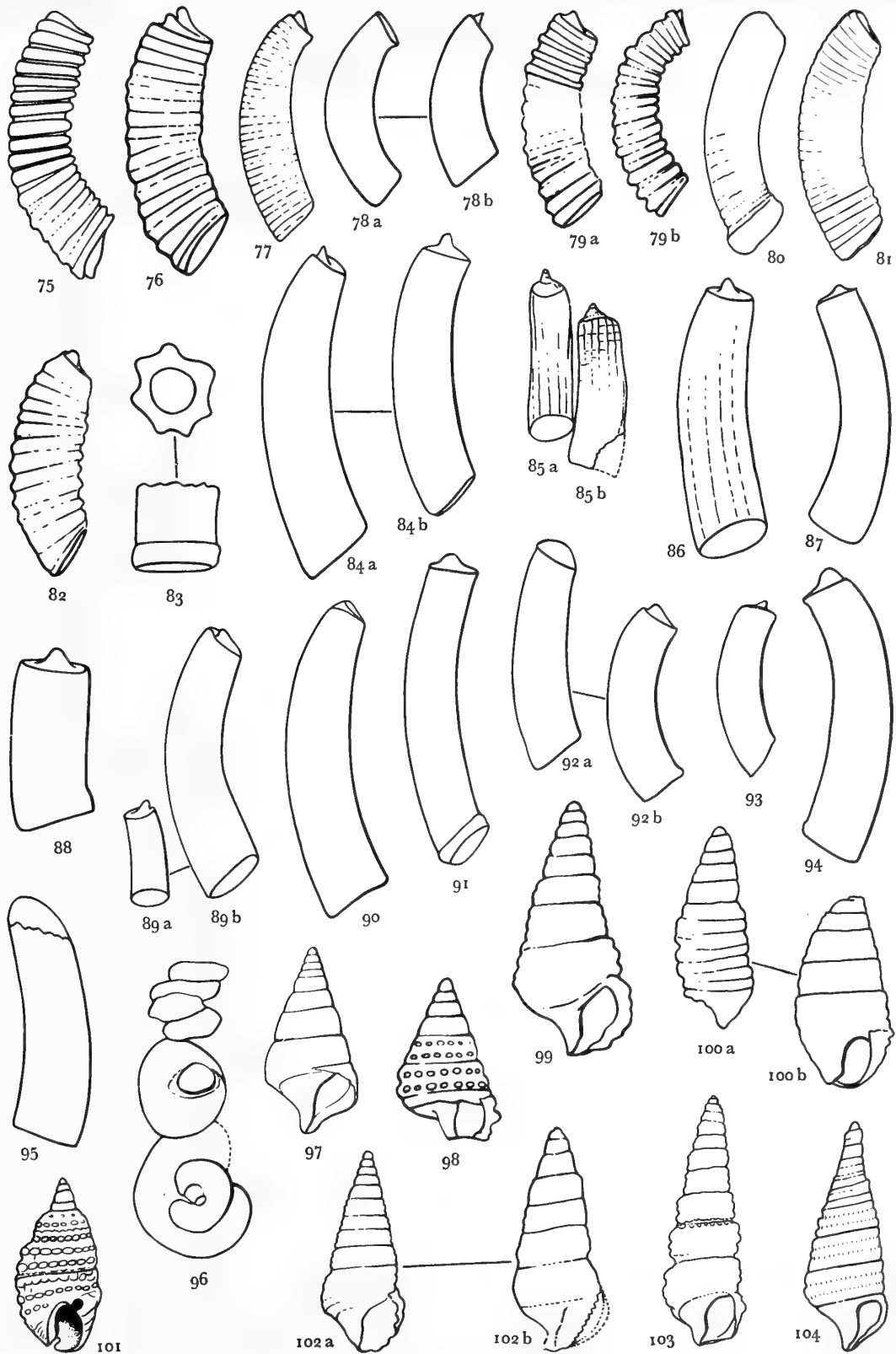
Figure 100: *Cerithiopsis pupiformis*. Syntypes. a) juvenile; b) broken adult. Length of each, 2.2 mm (x 14).

Figure 101: *Cerithiopsis sorex*. Syntype. Length, 2 mm (x 14).

Figure 102: *Cerithiopsis tuberculoides*. Syntypes. a) Length, 2.4 mm (x 13); b) Length, 4.6 mm (x 8).

Figure 103: *Cerithiopsis convexa*. Holotype. Length, 5.6 mm (x 7).

Figure 104: *Cerithiopsis decussata*. Holotype. Length, 5.2 mm (x 7).



90. *Ianthina decollata*, "nom. prov." p. 187  
 = *Janthina prolongata* BLAINVILLE, 1822  
 (Plate 59, Figures 78 a-c)

Tablet 878, 3 syntypes. [26 mm].

Carpenter had justifiable misgivings about the distinctness of this form.

#### LITTORINIDAE

91. *Litorina philippii*, p. 349  
 = *Littorina dubiosa philippii* CARPENTER, 1857  
 (Plate 57, Figure 54)

Tablets 1671 - 1685, 109 syntypes (tablet 1676 photographed. [10 mm].

The numerous variants were arranged by Carpenter on 15 slides, of which one was photographed that he described as "zigzag at base."

#### VITRINELLIDAE

92. *Vitrinella orbis*, p. 247  
 = *Cyclostremella orbis* (CARPENTER, 1857)  
 (Text figure 41)

Tablet 1163, 1 syntype. [0.8 mm]. BRANN: plt. 25, fig. 312.

The shell is nearly smooth but shows one thin carina at the periphery and a fainter one above and below. PILSBRY & OLSSON (1952, p. 84) suggest the plausible allocation to *Cyclostremella*.

93. *Vitrinella bifrontia*, p. 242  
 = *Cyclostremiscus bifrontia* (CARPENTER, 1857)  
 (Text figure 42)

Tablet 1154, 1 syntype. [1.3 mm]. BRANN: plt. 24, fig. 303.

The allocation by PILSBRY & OLSSON (1952, p. 62), on the basis of another syntype, seems justified.

94. *Vitrinella coronata*, p. 244  
 = *Cyclostremiscus coronatus* (CARPENTER, 1857)  
 (Text figure 43)

Tablet 1157, 2 syntypes, the larger figured. [1.4 mm]. BRANN: plt. 24, fig. 306.

The allocation by PILSBRY & OLSSON (1952, p. 62) seems correct.

95. *Vitrinella lirulata*, p. 241  
 = *Cyclostremiscus lirulatus* (CARPENTER, 1857)  
 (Text figure 44)

Tablet 1151, holotype. [2.1 mm]. BRANN: plt. 23, fig. 300.

The species was allocated to *Cyclostremiscus* by PILSBRY & OLSSON (1952, p. 83). When studying the holotype I noted that it was nearest in form to their *Cyclostremiscus nummus* from Panama but lacked any peripheral carination.

96. *Vitrinella perparva*, var. *nodosa*, p. 243  
 = *Cyclostremiscus nodosus* (CARPENTER, 1857)  
 (Text figure 45)

Tablet 1155, holotype. [0.8 mm]. BRANN: plt. 24, fig. 304.

### Explanation of Plate 58

All specimens are in the British Museum (Natural History), Mollusca Section. They were photographed in place on glass mounts.

Generic and specific names are as cited by CARPENTER.

Figure 57: *Oliva intertincta*. Syntype, back view. Length, 20 mm (x 2).

Figure 58: *Litiopa divisa*. Syntype, from "Cape San Francisco." Length, 2.7 mm (x 10).

Figure 59: *Nassa nodulifera*. Holotype. Length, 16 mm (x 1.9).

Figure 60: *Nassa crebristriata*. Holotype. Length, 13.5 mm (x 2.7).

Figure 61: *Nassa acuta*. Syntype. Length, 20 mm (x 1.6).

Figure 62: *Mangelia subangulata*. Holotype. Length, 4.3 mm (x 6.5).

Figure 63: *Murex lividus*. Two syntypes. a) Length, 44 mm; b) Length, 40 mm (x 1).

Figure 64: *Muricidea indentata*. Holotype. Length, 34 mm (x 1.7).

Figure 65: *Pisania elata*. Two hypotypes, without definite locality, in British Museum collection as "*P. elata*, var." a) Length, 34 mm; b) Length, 37 mm (x 1).

Figure 66: *Erato panamensis*. Syntype, from Panama. Length, 7.5 mm (x 4.4).

Figure 67: *Melampus olivaceus*. Syntype. Length, 15 mm (x 3).

Figure 68: *Siphonaria aequilirata*. Holotype. Length, 17 mm (x 2.4).

Figure 69: *Siphonaria palmata*. Two syntypes. a) Length, 21 mm; b) Length, 29 mm (x 1.3).

Figure 70: *Terebra albocincta*. Longest of 5 syntypes on tablet 1828. Length, 42 mm (x 1.5).

Figure 71: *Terebra hindsii*. Two syntypes. a) Apertural view. Length, 31.5 mm; b) Back view. (x 1.8).

Figure 72: *Terebra subnodosa*. Syntype. Length, 33 mm (x 1.8).

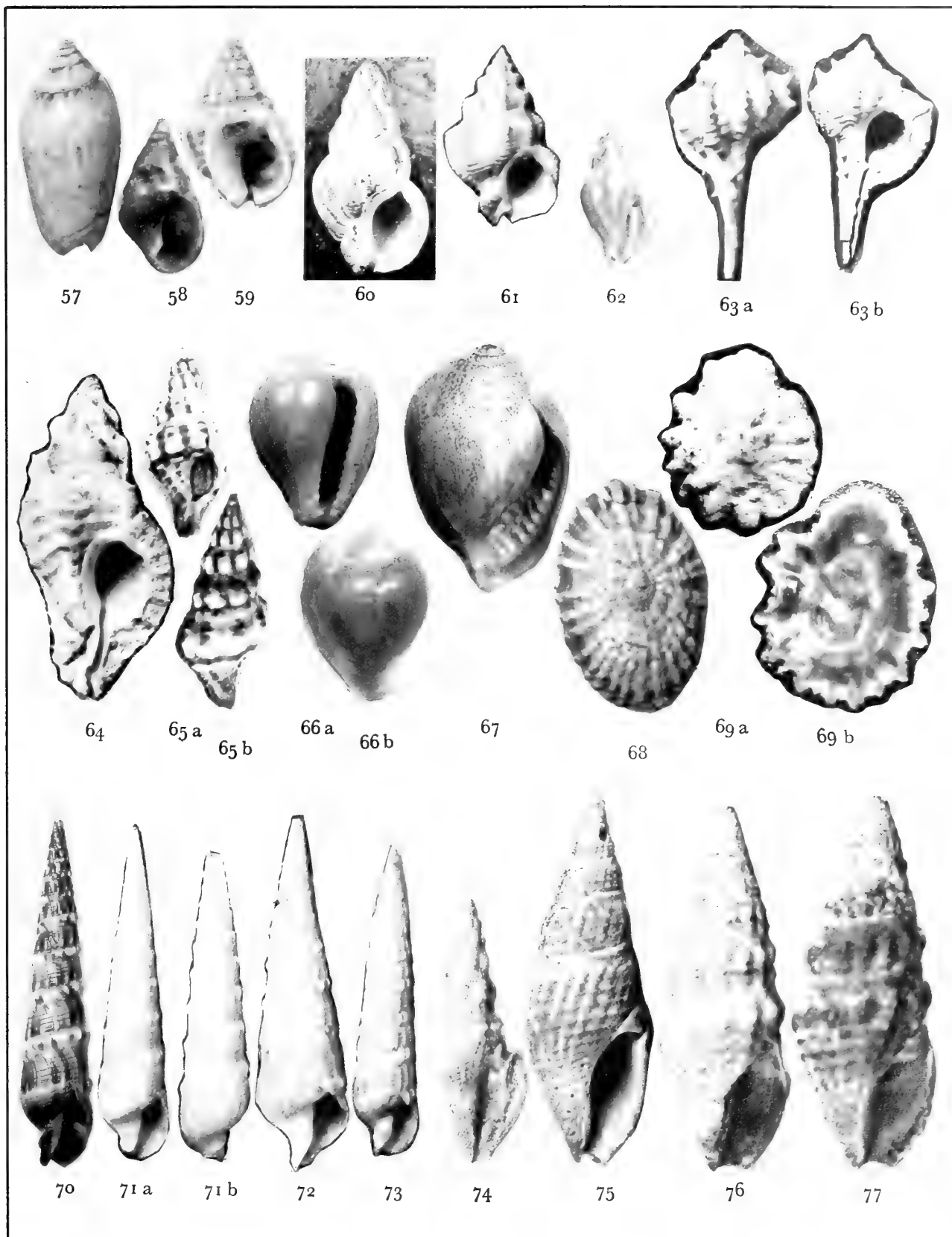
Figure 73: *Terebra rufocinerea*. Syntype. Length, 31 mm (x 1.8).

Figure 74: *Clathurella aurea*. Holotype. Length, 14.5 mm (x 3.5).

Figure 75: *Drillia punctatostriata*. Holotype from Panama. Length, 19 mm (x 3.5).

Figure 76: *Drillia monilifera*. Holotype. Length, 15.4 mm (x 4.2).

Figure 77: *Drillia cerithioidea*. Syntype. Length, 16 mm (x 4.2).





The allocation by PILSBRY & OLSSON (1952, p. 63) seems justified, but their figure of a supposed paratype may be of a specimen that is not conspecific, for the peripheral nodes are relatively larger than in the holotype, as shown both by my drawing and that of Carpenter.

97. *Vitrinella ornata* CARPENTER, 1864 b, p. 271  
 = *Cyclostremiscus ornatus* (CARPENTER, 1864)  
 (Text figure 46)

Tablet 2533, holotype. [0.9 mm]. BRANN: plt. 25, fig. 2535.

Although they did not have a figure for guidance, PILSBRY & OLSSON (1952, p. 82) seem to have allocated this correctly. Carpenter evidently labeled his figure "2535" by error. He described no. 2535 as only a fragment of a shell, whereas the figure given is of a complete specimen and the drawing matches well the specimen mounted on tablet no. 2533.

98. *Vitrinella tenuisculpta* CARPENTER, 1864 b, p. 271  
 = *Cyclostremiscus tenuisculptus* (CARPENTER, 1864)  
 (Text figure 47)

Tablet 2534, holotype [0.7 mm]. BRANN: plt. 25, fig. 2534.

PILSBRY & OLSSON (1952, p. 83) seem to have allocated the form correctly. Carpenter's drawing somewhat exaggerates the dorsal curve and hence the outline of the shell. My own drawing suggests a more lenticular form.

99. *Vitrinella trigonata*, p. 244  
 = *Cyclostremiscus trigonatus* (CARPENTER, 1857)

Tablet 1156, hypotype. [0.6 mm]. BRANN: plt. 24, fig. 305, as *Vitrinella exigua* C. B. ADAMS, 1852.

Carpenter's specific name could be rejected as having been proposed in synonymy, for it was a name he had used in manuscript and merely mentioned in his discussion of *Vitrinella exigua*. PILSBRY & OLSSON (1945, pp. 268 - 269), however, consider that Adams' species is a secondary homonym of *Delphinula exigua* PHILIPPI, 1845, which also seems to be a *Cyclostremiscus*. Thus, they reject the name *exigua* and substitute *trigonata* of Carpenter. Although names proposed in synonymy are to be rejected under Article 11 of the International Code of Zoological Nomenclature, this Article has been modified in the second edition of the Code to provide that if such a name has, prior to 1961, been treated as available, it may be accepted, with its original date and authorship. Thus, *V. trigonata* may be utilized. The holotype, of course, remains that of Adams, not the figured specimen on tablet 1156.

100. *Vanicoro cryptophila*, p. 262  
 = *Macromphalina cryptophila* (CARPENTER, 1857)  
 (Text figure 48)

Tablets 1313 - 1315. [4 mm]. BRANN: plt. 28, fig. 330.

Carpenter's drawings show well the tilted apex (which is brown in color) and the sculpture of *Macromphalina*. I had the impression when observing some of the juvenile specimens under the microscope that one or two might be *Vanikoro*. I am therefore designating the adult in tablet 1314, shown also in my drawing, as the lectotype. The adult in tablet 1315, which will thus become a lectoparatype, is in place in a crevice of a *Spondylus* fragment; it shows fine spiral sculpture in the body whorl.

101. *Vitrinella planospirata*, p. 246  
 = ?*Miralabrum planospiratum* (CARPENTER, 1857)  
 (Text figure 49)

Tablet 1162, holotype. [ca. 5 mm]. BRANN: plt. 24, fig. 311.

The shell is represented by a fragment only, and Carpenter's attempt at a restoration is highly fanciful. The sculpture and size suggest *Miralabrum* PILSBRY & OLSSON (1945, p. 276), the type of which, also incomplete, is from Ecuador (*M. unicornis*). A specimen of *Miralabrum* has been found by Faye Howard at Cape San Lucas that may represent Carpenter's species; a photograph of this shell is given here for comparison (Plate 59, Figure 102). The size (diameter 4.7 mm) compares well with Carpenter's estimate of probable size of his holotype.

102. *Vitrinella cincta*, p. 245  
 = *Lydiaphnis (Cymatopteryx) cincta* (CARPENTER, 1857)  
 (Text figure 50)

Tablet 1159, holotype. [0.8 mm]. BRANN: plt. 25, fig. 308.

PILSBRY & OLSSON (1952, p. 83) suggest that this species should be allocated to *Cyclostremiscus*, but studying the holotype and comparing it with their figures I noted that it was closest to their figure of *Lydiaphnis strongi*. Therefore, I revise their assignment.

103. *Vitrinella decussata*, p. 239  
 = *Parviturboides decussatus* (CARPENTER, 1857)  
 (Text figure 51)

Tablet 1148, 6 syntypes. [1.1 mm]. BRANN: plt. 23, fig. 297.

PILSBRY & OLSSON (1952, p. 68; plt. 11, figs. 3, 3a-b) have correctly reallocated this species; their figure is of a "paratype" [*i. e.*, syntype].

104. *Vitrinella monile*, p. 240

= *Parviturboides monile* (CARPENTER, 1857)  
(Text figure 52)

Tablet 1149, 4 syntypes. [1.4 mm]. BRANN: plt. 23, fig. 298.

Carpenter's drawing as published by Brann confirms the allocation to *Parviturboides* made by PILSBRY & OLSSON (1952, p. 84). My own drawing may not be entirely accurate as to outline, due to my faulty adjustment of the camera lucida device, and his is definitely tilted.

105. *Vitrinella monilifera*, p. 240

= ?*Parviturboides monilifer* (CARPENTER, 1857)  
(Text figure 53)

Tablet 1150, 1 syntype. [1 mm]. BRANN: plt. 23, fig. 299.

The allocation to *Parviturboides* has been suggested by PILSBRY & OLSSON (1952, p. 84). My notation when studying the syntype was that it might be a juvenile *Solariorbis*. The lenticular outline would be more in harmony with such an allocation, but the sculpture and evenly curved inner lip are reminiscent of *Parviturboides*.

106. *Vitrinella annulata*, p. 245

= *Solariorbis* (*Systellomphalus*) *annulatus* (CARPENTER, 1857)  
(Text figure 54)

Tablet 1158, holotype. [1.3 mm]. BRANN: plt. 25, fig. 307.

It is doubtful if PILSBRY & OLSSON (1952, p. 83) had an adequate figure of Carpenter's material, else they could not have suggested an assignment to *Cyclostremiscus* for this smooth-spined form. It closely resembles the Ecuadorean Pliocene species that is the type of *Systellomphalus* but differs in the arrangement of the basal cords. PILSBRY & OLSSON described *Systellompha-*

*lus* as a genus in 1941 but by 1952 (p. 51) demoted it to a species-group rank. However, it seems to me to have sufficient distinctness to be usefully retained as a sub-genus under *Solariorbis*.

107. *Globulus* (*Ethalia*) *carinata*, p. 252

= ?*Solariorbis carinatus* (CARPENTER, 1857)  
(Text figure 55)

Tablet 1172, 1 syntype. [0.9 mm]. BRANN: plt. 28, fig. 321.

With some hesitation I accept the allocation to *Solariorbis* of PILSBRY & OLSSON (1952, p. 83). When I was examining Carpenter's specimen and comparing it with the Pilsbry and Olsson figures, I concluded that it best matched that of *Cyclostremiscus tricarinatus* (C. B. ADAMS, 1852) but that it had a weaker upper keel, a lower spire, and a shallower umbilicus.

108. *Vitrinella carinulata*, p. 246

= *Solariorbis carinulatus* (CARPENTER, 1857)  
(Text figure 56)

Tablet 1160, holotype. [0.8 mm]. BRANN: plt. 25, fig. 309.

The figure by PILSBRY & OLSSON (1952, plt. 13, figs. 4a, 4b) is a good representation of the form, but the specimen (now at Harvard) cannot be a paratype, for Carpenter cited only a single example. My drawing is a little distorted obliquely, due to my faulty adjustment of the camera lucida attachment.

109. *Globulus* (*Ethalia*) *pyriccallosa*, p. 251

= *Solariorbis pyriccallosus* (CARPENTER, 1857)  
(Text figure 57)

Tablet 1169, holotype. [1.2 mm]. BRANN: plt. 26, fig. 318.

## Explanation of Text figures 105 to 128

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 105: *Alaba laguncula*. Holotype. Sketch (about  $\times 22$ ).

Figure 106: *Alaba mutans*. Holotype. Length, 2.6 mm ( $\times 11$ ).

Figure 107: *Alaba scalata*. Holotype. Length, 1 mm ( $\times 23$ ).

Figure 108: *Alaba terebralis*. Holotype. Length, 1.8 mm ( $\times 19$ ).

Figure 109: *Alaba violacea*. Holotype. Length, 1.8 mm ( $\times 17$ ).

Figure 110: *Alvania effusa*. Holotype. Length, 3.6 mm ( $\times 8$ ).

Figure 111: *Alvania excurvata*. Syntype. Length, 3.6 mm ( $\times 8$ ).

Figure 112: *Hipponyx planatus*. Syntypes. a) Diameter, 1.8 mm ( $\times 8$ ); b) Diameter, 5 mm ( $\times 4.5$ ).

Figure 113: *Fossarus tuberosus*. Syntype. Length, 1.5 mm ( $\times 23$ ).

Figure 114: *Crepidula bilobata*. Syntype. Diameter, 4 mm ( $\times 8$ ).

Figure 115: *Anachis gaskoini*. After Carpenter's sketch of holotype. Length, 6 mm ( $\times 6$ ).

Figure 116: *Anachis serrata*. Syntype. Length, 3.9 mm ( $\times 9$ ).

Figure 117: *Fusus apertus*. Syntype. Length, 4.6 mm ( $\times 7$ ).

Figure 118: *Fusus tumens*. Syntype. Length, 5 mm ( $\times 7$ ).

Figure 119: *Marginella margaritula*. Lectotype. a) Length, 2.2 mm ( $\times 11$ ); b) and c), paralectotypes, apertural and back views. Length, 2.1 mm ( $\times 11$ ).

Figure 120: *Marginella polita*. a) Paralectotype. Length, 0.9 mm ( $\times 25$ ); b) lectotype. Length, 1.1 mm ( $\times 26$ ); c) detail of anterior part of aperture, tilted forward.

Figure 121: *Drillia cerithioidea*. Syntype. Length, 15 mm ( $\times 2.3$ ).

Figure 122: *Mangelia sulcata*. Holotype. Length, 5.6 mm ( $\times 7$ ).

Figure 123: *Mangelia subangulata*. Holotype. Length, 4.3 mm ( $\times 7$ ).

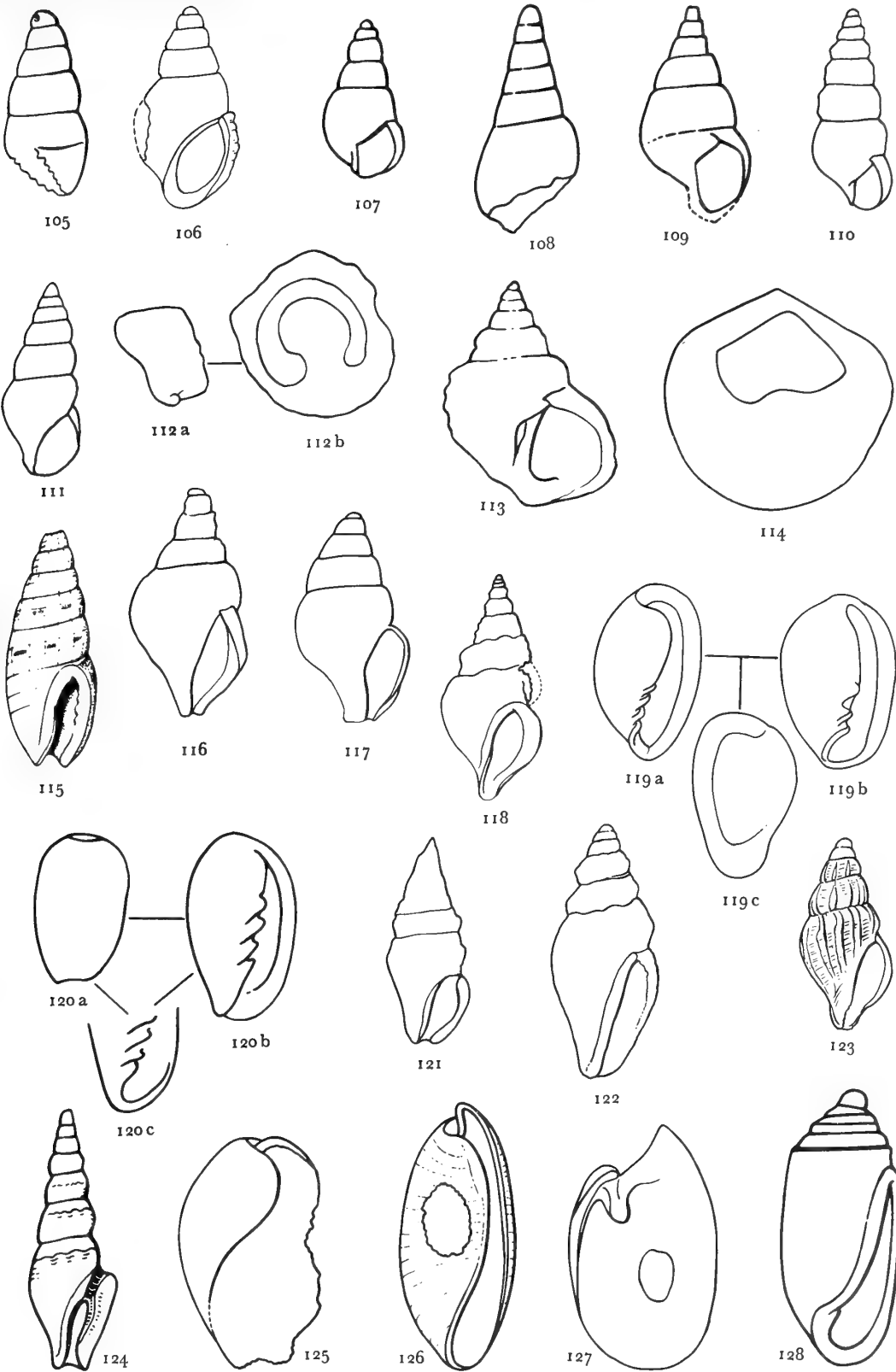
Figure 124: *Clathurella aurca*. Holotype. Length, 15 mm ( $\times 2.5$ ).

Figure 125: *Haminea cymbiformis*. Holotype. Length, 2.7 mm ( $\times 13$ ).

Figure 126: *Bulla exarata*. Syntype. Length, 3.8 mm ( $\times 10$ ).

Figure 127: *Smaragdinella thecaphora*. Holotype. Length, 2.4 mm ( $\times 15$ ).

Figure 128: *Tornatina carinata*. Syntype. Length, 3.2 mm ( $\times 13$ ).



The allocation to *Solariorbis* by PILSBRY & OLSSON, (1952, p. 82) seems justifiable.

110. *Teinostoma amplexans*, p. 253

= *Teinostoma (Pseudorotella) amplexans* CARPENTER, 1857

(Text figure 58)

Tablet 1174, holotype. [3 mm]. BRANN: plt. 26, fig. 323 (also figured by SOWERBY in REEVE, 1874, Conch. Icon., vol. 19, plt. 1, figs. 1a-c, from a specimen in the British Museum).

The figure of *Teinostoma americanum* PILSBRY & OLSSON, 1945 (plt. 23, fig. 3), a southern variant of this species, is a good representation of the form except for the slightly smaller size. In 1952 (p. 41) they allocated both forms to the subgenus *Pseudorotella*.

111. *Globulus (Ethalia) amplexans*, p. 253

= ?*Teinostoma amplexans* CARPENTER, 1857

(Text figure 59)

Tablet 1173, 1 syntype. [1 mm]. BRANN: plt. 26 fig. 322.

PILSBRY & OLSSON (1952, p. 82) allocated this to *Solariorbis*, probably not having seen a good figure. Both Carpenter's drawing as published by BRANN and my own suggest the strong umbilical callus of *Teinostoma*. Carpenter himself was not sure but that this might be the

young of *T. amplexans* – hence his choice of the same specific name for both. The shell is translucent and relatively thick; my notes suggest that it may be a young of *T. lirulatum*.

112. *Globulus (Ethalia) lirulata*, p. 251

= *Teinostoma lirulatum* (CARPENTER, 1857)

(Text figure 60)

Tablet 1170, 1 syntype. [1 mm]. BRANN: plt. 26, fig. 319.

As with the previous form, PILSBRY & OLSSON (1952, p. 82) allocated this to *Solariorbis*. The callus seems to me to be too well developed for that. I noted when examining the holotype that the closest figure in the PILSBRY & OLSSON monographs was their *Teinostoma ecuadorianum* (1952, plt. 3, fig. 5), but *T. lirulatum* has, as the specific name suggests, fine spiral sculpture.

113. *Globulus (Ethalia) pallidula*, p. 252

= ?*Teinostoma pallidulum* (CARPENTER, 1857)

(Text figure 61)

Tablet 1171, holotype. [1.1 mm]. BRANN: plt. 26, fig. 320.

The large aperture and relatively small diameter of this shell are peculiar. PILSBRY & OLSSON (1952, p. 82) considered it to be a *Solariorbis*, but it seems to me that the outline is closer to that of a *Teinostoma*, such as *T.*

## Explanation of Plate 59

All specimens are in the British Museum (Natural History), Mollusca Section. They were photographed in place on glass mounts.

Generic and specific names are as cited by CARPENTER.

Figure 78: *Janthina decollata*. Three syntypes. Diameter of largest, 25 mm (x 1.1).

Figure 79: *Janthina striulata*. Syntype. Diameter, 17 mm (x 1.6).

Figure 80: *Janthina contorta*. Syntype. Diameter, 21 mm (x 1.1).

Figure 81: *Sistrum rufonotatum*. Three syntypes, from Cape San Lucas, Baja California. Length of largest, 12 mm (x 2).

Figure 82: *Anachis albonodosa*. Syntype. From a color photograph by Elaine Reeves. Length, 3 mm (x 10).

Figure 83: *Anachis pachyderma*. Two syntypes. Length of larger, 16 mm (x 2.4).

Figure 84: *Columbella cervinetta*. Holotype. Length, 7.8 mm (x 5.5).

Figure 85: *Columbella obsoleta*. Syntype. Length, 6 mm (x 5.5).

Figure 86: *Anachis gaskoini*. Hypotype, from Peru. Length, 6.5 mm (x 5.5).

Figure 87: *Anachis serrata*. Two syntypes. a) Apertural view; Length, 3.1 mm; b) Back view (specimen here selected as lectotype); Length, 3.5 mm. From a color photograph by Elaine Reeves. (x 8).

Figure 88: *Olivella aureocincta*. Two syntypes. a) Apertural view; b) Back view. Length, 8.3 mm (x 3.5).

Figure 89: *Olivella glandinaria*. Two syntypes, from California, Nuttall collection. Length of larger, 25 mm (x 1.1).

Figure 90: *Pisania acquirilata*. Holotype. Length, 25.5 mm (x 1.6).

Figure 91: *Lophyrus striatosquamosus*. Holotype. Length, 4.5 mm (x 8).

Figure 92: *Acanthochites arragonites*. Syntype (here selected as lectotype). Length, 3.0 mm (x 11).

Figure 93: *Lepidopleurus macandreae*. Holotype. Length, 3.3 mm (x 11).

Figure 94: *Lepidopleurus beanii*. Syntype (here selected as lectotype). Length, 6 mm (x 7).

Figure 95: *Lepidopleurus bullatus*. Syntype (here selected as lectotype). Length, 4.5 mm (x 8).

Figure 96: *Lepidopleurus calciferus*. Holotype. Length, 3.3 mm (x 10).

Figure 97: *Lepidopleurus clathratus*. Holotype. Length, 4.4 mm (x 8).

Figure 98: *Drillia albovallosa*. Holotype. Length, 10 mm (x 4.2).

Figure 99: *Drillia hanleyi*. Holotype. Length, 10 mm (x 4).

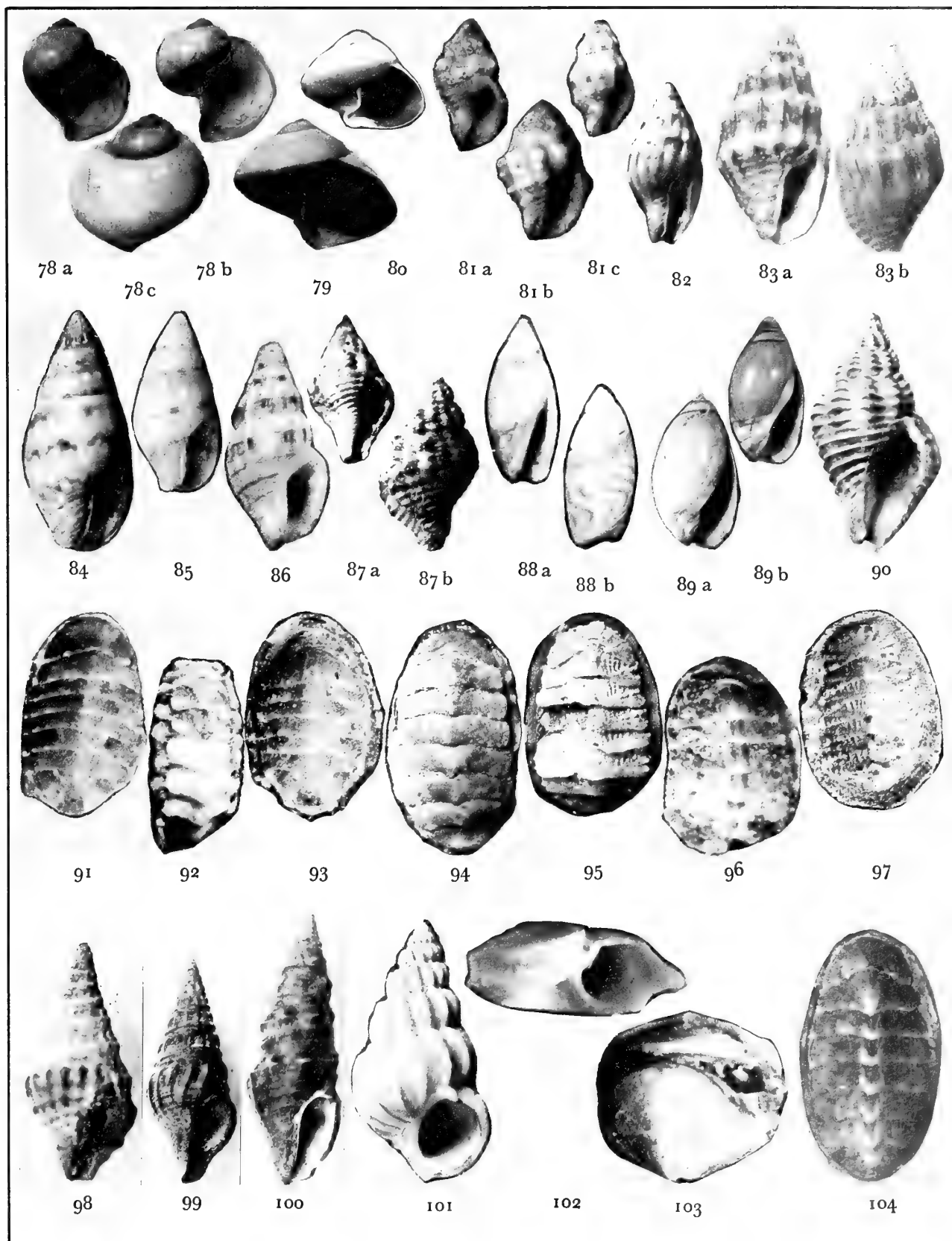
Figure 100: *Drillia albonodosa*. Lectotype (here selected). Length, 13 mm (x 3.6).

Figure 101: *Scalaria suprastrata*. Syntype. Length, 11.5 mm (x 4).

Figure 102: *Miralabrum* sp., cf. ?*M. planospirata* (CARPENTER). Hypotype from Cape San Lucas, Baja California, collected by Faye Howard. Diameter, 4.7 mm (x 8).

Figure 103: *Chiton flavescens*. Syntype. Length about 6 mm (x 10).

Figure 104: *Toncia forbesii*. Syntype (here selected as lectotype). Length, 19 mm (x 2.4).





*rarum* PILSBRY & OLSSON, 1945 (plt. 23, fig. 2). There is no umbilical chink, and the shell has a fine punctate spiral sculpture. The small size suggests immaturity.

114. *Teinostoma substriatum*, p. 254

= *Teinostoma substriatum* CARPENTER, 1857  
(Text figure 62)

Tablet 1175, syntype. [1.1 mm]. BRANN: plt. 26, fig. 324 (figured also by Sowerby in REEVE, 1874 (Conch. Icon., vol. 19, plt. 1, fig. 4, from a specimen in the British Museum).

PILSBRY & OLSSON (1952, p. 43, plt. 11, fig. 2) have illustrated a "paratype" (actually a syntype) that, although an imperfect specimen, seems to be conspecific with the specimen in the British Museum. The umbilical callus is less well developed than in other species, but there is no chink at its margin.

115. *Globulus sulcatus*, p. 250

= *Teinostoma sulcatum* (CARPENTER, 1857)  
(Text figure 63)

Tablet 1168-b, 1 syntype. [0.7 mm]. BRANN: plt. 26, fig. 317-b.

Carpenter published this name provisionally and did not cite a separate tablet number, indicating that he had mounted one of two specimens on the card with the type of his *Globulus tumens*. The British Museum specimen now becomes secondary, for PILSBRY & OLSSON (1952, p. 44; plt. 3, fig. 3) selected the other of Carpenter's two specimens as lectotype (citing it, however, as "holotype"). It was at that time in the collection of the New York State Museum but has since been transferred to the Museum of Comparative Zoology at Harvard University on permanent loan. Their figure accords well with my sketch of the British Museum specimen. Whether the furrow on the callus has any morphological significance remains to be seen.

116. ?*Globulus tumens*, p. 250

= *Teinostoma tumens* (CARPENTER, 1857)  
(Text figure 64 a-b)

Tablet 1168, 1 syntype. [—]. BRANN: plt. 26, fig. 317.

PILSBRY & OLSSON (1952, p. 43) correctly allocated this to *Teinostoma*.

117. *Vitrinella biflata*, p. 241

= *Vitrinella biflata* CARPENTER, 1857  
(Text figure 65)

Tablet 1153, 2 syntypes. [1.4 mm]. BRANN: plt. 24, fig. 302.

This has been figured from a "paratype" [*i.e.* syntype] in the New York State Museum collection (now on permanent loan to Harvard University) by PILSBRY & OLSSON (1952, p. 75; plt. 11, fig. 1).

118. *Vitrinella naticoides*, p. 246

= ?*Vitrinella naticoides* CARPENTER, 1857  
(Text figure 66)

Tablet 1161, 1 syntype. [1.2 mm]. BRANN: plt. 25, fig. 310.

PILSBRY & OLSSON (1952, p. 73; plt. 11, fig. 4) illustrated a "paratype" that was in the New York State Museum collection (now at Harvard University on permanent loan). It is similar in form to the syntype at the British Museum. On the basis of the spiral cord that makes the inner lip of the aperture of uneven width, I should have supposed this would be a *Solariorbis*. They, however, retain it in *Vitrinella* with a query.

119. *Vitrinella subquadrata*, p. 241

= *Vitrinella subquadrata* CARPENTER, 1857  
(Text figure 67)

Tablet 1152, 4 syntypes. [1 mm]. BRANN: plt. 23, fig. 301.

PILSBRY & OLSSON (1952, p. 76; plt. 11, fig. 5) have figured a "paratype" [*i.e.* syntype] that was then in the New York State Museum (now at Harvard University on permanent loan). The figure accords well with that of the best syntype drawn by Carpenter. My own drawing is a freehand sketch intended only to show general features.

120. *Vitrinella clathrata*, p. 238

Invalid name

This name was given in the synonymy of *Vitrinella parva* C. B. ADAMS, 1852. It was a manuscript name that Carpenter abandoned when he studied Adams' Panamic material, and it falls as a name proposed in synonymy.

## RISSOIDAE

121. *Alvania tumida*, p. 360

= *Alvania (Alvinia) tumida* CARPENTER, 1857  
(Text figure 68)

Tablet 1711, 1 syntype. [1.4 mm]. BRANN: plt. 39, fig. 414.

BARTSCH (1911 d, p. 361; plt. 32, fig. 2) has given a figure of a specimen from the U. S. National Museum collection that seems to be correctly identified.

122. *Alaba mutans*, p. 369

= ?*Alvania (Lapsigyrus) mutans* (CARPENTER, 1857)  
(Text figure 106)

Tablet 1729, holotype. [2.2 mm]. BRANN: plt. 40, fig. 431.

The back of the body whorl is broken away in the holotype, which explains Carpenter's choice of side-view for the drawing. The spiral ribs are not so strong as he would make them, and there is a channeled suture, as shown in my drawing, though he does not indicate it. The

apex is slightly sunken. I had hoped that this would provide a name that could be salvaged for the "*Alvania lirata*" of authors, but direct comparison of specimens ruled this out. No nodes develop above the suture, the aperture is more oblique, and the spire is more tapering. The shell is closer to the type species of *Lapsigyrus* BERRY, 1958 (Leaflets in Malacology, vol. 1, no. 16, p. 92), a Pleistocene form from Magdalena Bay — *Alvania conreri* JORDAN, 1936 (Contributions, Department of Geology, Stanford University, vol. 1, no. 4, p. 160; plt. 19, fig. 9). As compared to Jordan's figure, Carpenter's shell is smaller, the aperture is shorter, and the spiral sculpture is finer. If these differences prove to be consistent for the Recent form (the mention by Berry of fine sculpture in his report of specimens from the Sonoran coast suggests such a possibility), Carpenter's specific name may indeed have utility.

123. *Aclis fusiformis*, p. 437

= ?*Onoba fusiformis* (CARPENTER, 1857)  
(Text figure 69)

Tablet 2016, 2 syntypes. [1.6 mm]. BRANN: plt. 48, fig. 545.

At first glance one would take this for a pyramidellid, for the apex is sunken and folded over at the back as if heterostrophic. Bartsch evidently rejected it from Pyramidellidae, however, when he examined the types at the British Museum. Although the columella is twisted, it does not really bear a fold. The sculpture is pitted, in the manner of *Acteon*, but it lacks other characters of that

genus. The outline seems nearest to that of the rissoid genus *Onoba*, and there is a first record of that group in the West American fauna as *O. fortis* PILSBRY & OLSSON, 1941 (Proc. Acad. Nat. Sci. Philadelphia, vol. 93, p. 45; plt. 8, fig. 3), from the Pliocene of Ecuador. Several specimens from beach drift taken at Salinas, Ecuador, match their figure well, so that the species may be regarded as still living there. These specimens, in the Stanford University collection, have the apical whorls in good condition; the apex is acute, not sunken as in Carpenter's Mazatlan specimens. I therefore make the allocation with considerable doubt.

### RISSEOELLIDAE

124. *Jeffreysia bifasciata*, p. 362

= *Rissoella bifasciata* (CARPENTER, 1857)  
(Text figure 70)

Tablet 1716, 3 syntypes. [1.4 mm]. BRANN: plt. 39, fig. 419.

The color bands show up well, especially on the back of the largest syntype and on the two smaller shells in apertural view. BARTSCH (1920, p. 162; plt. 12, fig. 2) has figured a specimen he calls "type" (probably a syntype).

I have collected live specimens intertidally in gravelly sand at Cape San Lucas. ROBERTSON (1962, Notulae Naturae, Acad. Nat. Sci. Philadelphia, no. 352, p. 1) has shown that the generic name *Rissoella* M. E. GRAY,

### Explanation of Text figures 129 to 158

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 129: *Odostomia lamellata*. Syntype. Length (incomplete), 2 mm (x 14).

Figure 130: *Odostomia subsulcata*. Syntype. Length, 1.4 mm (x 19).

Figure 131: *Odostomia vallata*. Syntype. Length, 1.6 mm (x 17).

Figure 132: *Odostomia convexa*. Syntype. Length, 2.3 mm (x 11).

Figure 133: *Odostomia effusa*. Holotype. Length, 2.6 mm (x 12).

Figure 134: *Odostomia fasciata*. Syntype. Length, 2.5 mm (x 11).

Figure 135: *Odostomia nodosa*. Syntype. Length, 4.9 mm (x 7).

Figure 136: *Odostomia oblonga*. Syntype. Length, 4.9 mm (x 7).

Figure 137: *Odostomia ovata*. Syntype. Length, 4.9 mm (x 7).

Figure 138: *Odostomia ovulum*. Syntype. Length, 1.7 mm (x 16).

Figure 139: *Odostomia reigeni*. Holotype. Length, 1.7 mm (x 15).

Figure 140: *Odostomia rotundata*. Syntype. Length, 2.6 mm (x 12).

Figure 141: *Odostomia telescopium*. Syntype. Length, 4 mm (x 9).

Figure 142: *Odostomia lacunata*. Syntype. Length, 1.4 mm (x 19).

Figure 143: *Odostomia tenuis*. Syntype. Length, 1.8 mm (x 19).

Figure 144: *Chemnitzia intermedia*. Syntype. Length, 1.6 mm (x 19).

Figure 145: *Odostomia photis*. Syntype. Length, 1.4 mm (x 20).

Figure 158: *Chemnitzia paucilirata*. Holotype. Length, 2.7 mm (x 14).

Figure 146: *Odostomia quinquemaculata*. Syntype. Length, 1.8 mm (x 19).

Figure 147: *Odostomia clausiliformis*. Syntype. Length, 3.5 mm (x 10).

Figure 148: *Odostomia subilirulata*. Holotype. Length, 2.3 mm (x 14).

Figure 149: *Odostomia ziziphina*. Holotype. Length, 1 mm (x 23).

Figure 150: *Odostomia armata*. Syntype. Length, 2.5 mm (tilted) (x 11).

Figure 151: *Odostomia exarata*. Hypotype. Length, 2.9 mm (x 11).

Figure 152: *Odostomia mammillata*. Holotype. Length, 1.4 mm (x 18).

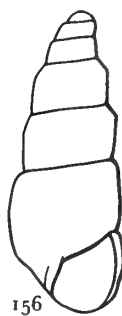
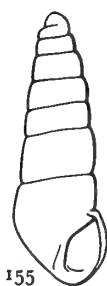
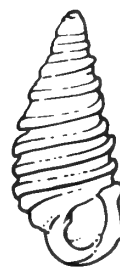
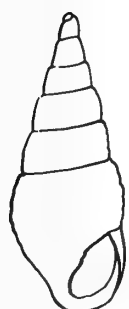
Figure 153: *Odostomia scalariformis*. Syntype. Length, 3 mm (x 11).

Figure 154: *Fossarus maculosa*. Syntype. Length, 4 mm (x 8).

Figure 155: *Chemnitzia muricata*. Syntype. Length, 2.8 mm (x 14).

Figure 156: *Chemnitzia subangulata*. Syntype. Length, 2.6 mm (x 14).

Figure 157: *Chemnitzia cancellata*. Holotype. Length, 1.2 mm (x 26).



March 1850, takes precedence over *Jeffreysia* FORBES & HANLEY, May, 1850.

125. *Jeffreysia tumens*, p. 363

= *Rissoella tumens* (CARPENTER, 1857)  
(Text figure 71)

Tablet 1719, 2 syntypes. [1.2 mm]. BRANN: plt. 39, fig. 421.

The specimen figured by BARTSCH (1920, pp. 160-161; plt. 12, fig. 1) seems to be correctly identified. The shell figured by BAKER, HANNA, & STRONG (1930, p. 36; plt. 1, fig. 13) has a more pointed apex and a small umbilicus.

126. ?*Jeffreysia alderi*, p. 362

= *Barleeia alderi* (CARPENTER, 1857)  
(Text figure 72)

Tablet 1718, 3 syntypes. [1.7 mm]. BRANN: plt. 39, fig. 420.

The allocation to *Barleeia* was made by BARTSCH (1920, p. 175; plt. 12, fig. 6). BAKER, HANNA, & STRONG (1930, p. 38) also have given a figure of a specimen, neither illustration being of type material.

#### RISSOINIDAE

127. *Rissoina woodwardii*, p. 357

= *Rissoina woodwardii* CARPENTER, 1857  
(Text figure 73)

Tablets 1706-1707, 13 syntypes. [3.1 mm]. BRANN: plt. 39, fig. 410 (also figured by Sowerby in REEVE 1878 (Conch. Icon., vol. 20, *Rissoa* plt. 11, fig. 104).

In his manuscript plates (published by BRANN) Carpenter omitted the numeral for tablet 1707, which should be below the figure to the right of "410" on plate 39. There seem to be no problems with this form, of which Carpenter had 15 syntypes. There are now only 13 entire shells and two fragments. Carpenter cited one unusually large specimen as length 4.1 mm. My drawing of the largest indicated 3.6 mm.

128. ?*Rissoa lirata*, p. 358

= ?*Rissoina* (*s.l.*) *lirata* (CARPENTER, 1857)  
(Text figure 74)

Tablet 1708, 2 syntypes. [4 mm]. BRANN: plt. 39, fig. 411.

Instead of publishing Carpenter's manuscript drawing, as he did for other Mazatlan forms, BARTSCH (1911, p. 338; plt. 29, fig. 3) illustrated a specimen from the U. S. National Museum collection, and his figure has been the basis for the misidentification of a relatively common form as "*Alvania lirata* CARPENTER." Carpenter described and his figure shows an operculum with an apophysis, like that of *Rissoina*; the operculum is still in place on the tablet. In his errata (page 552) he transferred the

species to *Barleeia*. The figured syntype (here chosen as lectotype) is more slender and tapering than "*A. lirata*" of authors, with regular spiral riblets crossed by a few low, angular axial ribs; there are faint color bands, and the suture is smoothly appressed, not channeled or bordered by nodes. A specimen in the California Academy of Sciences collection from San Francisco Bay, Gulf of California, matches the figure of Carpenter's type well.

If this form is correctly to be assigned to *Rissoina* it makes the fifth of a group of Gulf of California species having spiral sculpture predominating. The others listed by BAKER, HANNA, & STRONG (1930, p. 34) are: *R. lapazana* BARTSCH, 1915; *R. kelseyi* DALL & BARTSCH, 1902; *R. berryi* and *R. stephensae* BAKER, HANNA & STRONG, 1930. The group may prove to deserve a separate generic name or may turn out to be closer to *Diala*. At present we have insufficient knowledge about the type species of *Diala*.

#### CAECIDAE

129. *Caecum clathratum*, p. 322

= *Caecum clathratum* CARPENTER, 1857  
(Text figure 75)

Tablet 1528, 4 syntypes. [2.5 mm]. BRANN: plt. 34, fig. 369.

The largest of 4 syntypes is illustrated here.

130. *Caecum* ?*quadratum*, var. *compactum*, p. 322

= *Caecum compactum* CARPENTER, 1857  
(Text figure 76)

Tablet 1530, 7 syntypes. [-].

I have drawn the syntype that is third from the right on the tablet. Carpenter did not prepare a camera lucida drawing, not having been convinced of the validity of the form as separate. The syntypes comprise a growth series.

131. *Caecum elongatum*, p. 319

= *Caecum elongatum* CARPENTER, 1857  
(Text figure 77)

Tablet 1525, 4 syntypes. [2.6 mm]. BRANN: plt. 33, fig. 366.

My drawing is of the largest of 4 specimens on the tablet.

132. *Caecum farcimen*, p. 326

= ?*Caecum farcimen* CARPENTER, 1857  
(Text figure 78)

Tablet 1544, 4 syntypes. [1.6 mm]. BRANN: plt. 36, fig. 373.

There are 2 adult syntypes. Annulations are present though faint. Carpenter assigned this to his "section" *Fartulum*, which otherwise is made up of smooth forms.

133. *Caecum quadratum*, p. 322  
 = *Caecum quadratum* CARPENTER, 1857  
 (Text figure 79 a-b)

Tablet 1529, 7 syntypes. [1.8 mm]. BRANN: plt. 35, fig. 370.

I have drawn the two largest among the seven. There are about 17 somewhat flattened annulations, only the terminal ones being sketched in in my drawings.

134. *Caecum ?elongatum*, var. *semilaeve*, p. 319  
 = *Caecum semilaeve* CARPENTER, 1857  
 (Text figure 80)

Tablet 1526, 2 syntypes. [-].

I am illustrating the larger of the syntypes; the annulations are weak and irregularly developed. Carpenter did not prepare a camera lucida drawing for this form, as he was not confident of its validity.

135. *Caecum subimpressum*, p. 320  
 = *Caecum subimpressum* CARPENTER, 1857  
 (Text figure 81)

Tablet 1527, 7 syntypes. [3 mm]. BRANN: plt. 34, fig. 367.

My figure is of the largest syntype. The annulations are strong and recurved near the aperture.

136. *Caecum undatum*, p. 323  
 = *Caecum undatum* CARPENTER, 1857  
 (Text figure 82)

Tablets 1531 - 1538. [1.8 mm]. BRANN: plts. 35, 36, fig. 371.

Of the numerous syntypes, I have selected for my drawing the second from the right on tablet 1535. The shell resembles that of *Fartulum* but with low ribs, its surface otherwise shiny and smooth.

137. *Caecum heptagonum*, p. 319  
 = *Elephantanellum heptagonum* (CARPENTER, 1857)  
 (Text figures 83 a-b)

Tablet 1524, holotype. [0.5 mm]. BRANN: plt. 32, fig. 365.

This is the type species of the genus *Elephantanellum* BARTSCH, 1921. A figure of a better-preserved specimen has been given by STRONG & HERTLEIN (1939, p. 226; plt. 20, fig. 9) from Panama.

138. *Caecum liratocinctum*, p. 317  
 = *Elephantanellum liratocinctum* (CARPENTER, 1857)  
 (Text figures 84 a-b)

Tablets 1518 - 1519, 8 syntypes. [3.7 mm]. BRANN: plts. 32, 33, fig. 364.

My drawings are of the largest specimens on both tablets.

139. *Caecum liratocinctum*, var. *subconicum*, p. 318  
 = *Elephantanellum subconicum* (CARPENTER, 1857)  
 (Text figure 85)

Tablet 1522, 2 syntypes. [-]. BRANN: plt. 33, fig. 364 (part).

It may well be that this variety and the next are within the range of variation of the species. There are two specimens, one broken near the aperture, the other mounted with its convex side down.

140. *Caecum liratocinctum*, var. *subobsoletum*, p. 318  
 = *Elephantanellum subobsoletum* (CARPENTER, 1857)  
 (Text figure 86)

Tablet 1521, 2 syntypes. [-]. BRANN: plt. 33, fig. 364 (part).

141. *Caecum liratocinctum*, var. *tenuiliratum*, p. 318  
 = *Elephantanellum tenuiliratum* (CARPENTER, 1857)  
 (Text figure 87)

Tablet 1520, holotype. [-]. BRANN: plt. 33, fig. 364 (part).

One is tempted to transfer this form to *Elephantulum*, for there is little evidence of transverse sculpture. The longitudinal ribs are fine and sharply cut.

142. *Caecum abnormale*, p. 316  
 = *Elephantulum abnormale* (CARPENTER, 1857)  
 (Text figure 88)

Tablet 1516, 1 syntype. [1.2 mm]. BRANN: plt. 32, fig. 362.

143. *Caecum insculptum*, p. 315  
 = *Elephantulum insculptum* (CARPENTER, 1857)  
 (Text figures 89 a-b)

Tablet 1514, 2 syntypes. [3.3 mm]. BRANN: plt. 32, fig. 360.

The longitudinal ribs are well spaced on both syntypes, one of which Carpenter regarded as "old," the other "young."

144. *Caecum obtusum*, p. 317  
 = *Elephantulum obtusum* (CARPENTER, 1857)  
 (Text figure 90)

Tablet 1517, 2 syntypes. [3.2 mm]. BRANN: plt. 32, fig. 363.

I have drawn the larger of the two syntypes. The ribs have a worn look and are faint, more like internal lirae.

145. *Caecum subspirale*, p. 315= *Elephantulum subspirale* (CARPENTER, 1857)

(Text figure 91)

Tablet 1515, 4 syntypes. [4 mm]. BRANN: plt. 32, fig. 361.

Of the syntypes mentioned by Carpenter I have drawn the adult. The longitudinal ribs are numerous and with narrow interspaces.

146. *Caecum dextroversum*, p. 328= *Fartulum dextroversum* (CARPENTER, 1857)

(Text figure 92)

Tablet 1548, 9 syntypes. [2.3 mm]. BRANN: plt. 37, fig. 376.

I have drawn the two syntypes at the right of the tablet, one being an adult, the other juvenile.

147. *Caecum glabriforme*, p. 327= *Fartulum glabriforme* (CARPENTER, 1857)

Tablet 1546, originally 2 syntypes. [1.8 mm]. BRANN: plt. 37, fig. 374.

The young shell mentioned by Carpenter is now missing, and the adult has so deteriorated that it is unrecognizable. The species will have to be interpreted on the basis of Carpenter's drawing and description.

148. *Caecum reversum*, p. 329= *Fartulum reversum* (CARPENTER, 1857)

(Text figure 93)

Tablet 1549, holotype. [1.2 mm]. BRANN: plt. 37, fig. 377.

The specimen is glued to the tablet in such a way that the outline is hard to draw accurately.

149. *Caecum teres*, p. 329= ?*Fartulum teres* (CARPENTER, 1857)

(Text figure 94)

Tablet 1550, 3 syntypes. [3 mm]. BRANN: plt. 37, fig. 378.

Of the three syntypes mentioned by Carpenter, one is

now unrecognizable on account of chemical deterioration; another is partly decorticated. The remaining one is the largest. It shows banding, perhaps from wear, which Carpenter well characterized as "mottling." There are also some faint and irregular growth lines and a few weak longitudinal lines. One wonders if, when the shell was fresh, it may not have been recognizable as an *Elephantanellum* rather than a *Fartulum*, which Carpenter thought it might be.

150. *Caecum corrugulatum*, p. 327= ?*Micranellum corrugulatum* (CARPENTER, 1857)

(Text figure 95)

Tablet 1547, holotype. [1.9 mm]. BRANN: plt. 37, fig. 375.

The specimen is now an indeterminate broken tube filled with sediment. I suggest an allocation to *Micranellum* on the basis of Carpenter's drawing and description.

## VERMETIDAE

151. *Siphonium (Aletes) ?centiquadrus imbricatus*, p. 302= ?*Vermetus* sp., indet.

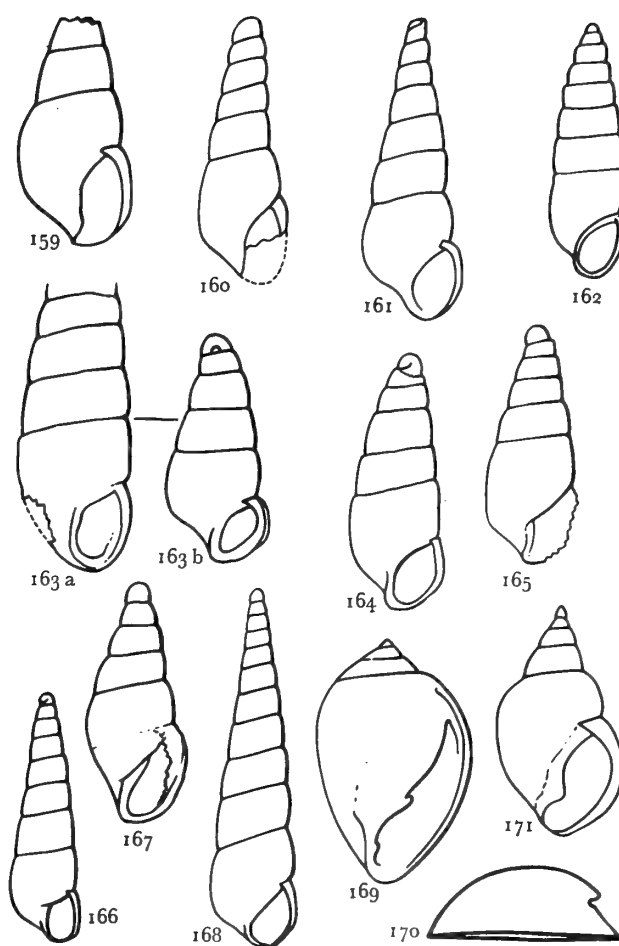
Tablet 1484, 1 syntype (?holotype). [Length, 15 mm; diameter of aperture, 3 mm].

Aware on my later visits to the British Museum that I had earlier concentrated on the Vermetidae, I was less rigorous in checking these slides, and thus I overlooked the fact that neither Carpenter nor I had sketched the specimen on slide 1484. I have therefore only the notes I made in 1958 when I decided that the shell is too immature for generic allocation. The coil has 2 to 3 whorls and is 15 mm in diameter; the sculpture is evenly striate rather than imbricate, as in *Serpulorbis*. However, were this to be allocated to *Serpulorbis* it would jeopardize the name of the well-known *S. imbricatus* (DUNKER, 1860) from Japan. Because young vermetids of less than 3 whorls cannot be assigned to a genus unless the nuclear

## Explanation of Textfigures 159 to 171

Note: Stated lengths are camera lucida readings and may be as much as 1/10 too high.

Figure 159: *Eulimella obsoleta*. Holotype. Length, 1.6 mm (x 19).Figure 160: *Chemnitzia flavescens*. Holotype. Length, 3.3 mm (x 11).Figure 161: *Chemnitzia gracillima*. Syntype. Length, 3.4 mm (x 11).Figure 162: *Odostomia indentata*. Syntype. Length, 4.6 mm (x 7.5).Figure 163: *Chemnitzia tenuilirata*. Syntypes. Length, a) 3 mm (incomplete) (x 12); b) 2 mm (x 16).Figure 164: *Chemnitzia terebralis*. Holotype. Length, 2.8 mm (x 12).Figure 165: *Chemnitzia unifasciata*. Holotype. Length, 2.6 mm (x 12).Figure 166: *Chemnitzia c-b-adamsii*. Syntype. Length, 4.6 mm (x 7.5).Figure 167: *Chemnitzia undata*. Syntype. Length, 2 mm (x 16).Figure 168: *Chemnitzia prolongata*. Syntype. Length, 6.4 mm (x 7.5).Figure 169: *Melampus olivaceus*. Syntype. Length, 12.5 mm (x 2.7).Figure 170: *Nacella peltoides*. Hypotype. Length, 3.7 mm (x 7).Figure 171: *Litiopa divisa*. Syntype. Length, 2.7 mm (x 11).



whorls and soft parts are preserved, it seems best to regard this variety as indeterminate.

Carpenter cited two specimens, one in good condition, the other worn. As he says that "Tablet 1484 contains the characteristic specimen," one might interpret this as holotype selection.

152. *Bivonia contorta*, p. 305

= *Vermetus (Thylaeodus) contortus* (CARPENTER, 1857)

Tablets 1489 - 1493, several syntypes. [23 mm].

The specimen on tablet 1490 was figured as lectotype by KEEN (1961, p. 201; plt. 55, fig. 3).

153. *Bivonia contorta*, var. *indentata*, p. 307

= *Vermetus (Thylaeodus) indentatus* (CARPENTER, 1857)

Tablet 1494, 3 syntypes. [13 mm].

The best of 3 specimens on this tablet was figured as lectotype by KEEN (1961, p. 202; plt. 55, fig. 4).

154. *Bivonia albida*, p. 307

Indeterminate vermetid

(Text figure 96)

Tablet 1495, 3 syntypes. [5.5 mm]. BRANN: plt. 31, fig. 356.

Carpenter's drawing and my own of the nuclear whorls agree well. He thought that one of the 3 syntypes was mature, but I do not find it identifiable. Several of the tropical West American vermetids have juvenile shells with this mode of coiling.

155. *Petalconchus macrophragma*, p. 309, "n. s."; CARPENTER, 1857 a [March], p. 313

= *Petalconchus (Macrophragma) macrophragma*

CARPENTER, 1857

Tablets 1499 - 1506. BRANN: plt. 30, fig. 359.

Carpenter's drawing is of the shell on tablet 1499, showing the internal laminae. A specimen on tablet 1500 was selected as lectotype by KEEN (1961, p. 205; plt. 55, fig. 2). There is a typographical error in BRANN's citation of the registry number, which is 57.6.4.1500 (not 1494). Carpenter validated the specific name prior to the publication of the Mazatlan Catalogue but based both descriptions on the same type material.

#### CERITHIIDAE

156. *Cerithium ?famelicum*, var. *mediolaeve*, p. 334

= *Cerithium mediolaeve* CARPENTER, 1857

(Plate 57, Figure 51)

Tablet 1587, holotype. [25 mm].

Because *Cerithium famelicum* C. B. ADAMS, 1852, has been ranked as a synonym of *C. uncinatum* (GMELIN, 1791), Carpenter's unillustrated variety has also been synonymized. However, the photograph shows that it is not only a smoother shell than *C. uncinatum*, with subdued color markings, but it is much more slender. The recurved canal and placement of sculptural elements relates it more closely to *C. nicaraguense* PILSBRY & LOWE, 1932, from which it differs in its slightly smaller size and more slender outline. Judging by the holotype, I conclude that this may be a distinct species and one to be watched for in West Mexican material.

157. *Cerithium alboliratum* p. 336,

= ?*Cerithium maculosum* KIENER, 1841

(Plate 57, Figure 48; Text figure 97)

Tablet 1591, 4 syntypes. [3.1 mm]. BRANN: plt. 38, fig. 385.

Carpenter's drawings illustrate 2 of the 4 syntypes. My drawing and photograph are of the only one now on the tablet that is unquestionably a *Cerithium*, and this specimen is here selected as lectotype. BAKER, HANNA, & STRONG (1938, p. 225; plt. 17, fig. 7) seem to have recognized the form correctly from Carpenter's description and from a figure by REEVE, 1866 (Conch. Icon., vol. 15, plt. 16, sp. 109) of a specimen said to be in the Cuming collection, British Museum. I am not convinced that this is a distinct species, for it seems to me to be the juvenile tip of *C. maculosum*. The other syntypes on the tablet are, I think, specimens of *Alabina* and *Bittium*.

158. *Cerithiopsis ?tuberculoides*, var. *albonodosa*, p. 443

= *Cerithiopsis tuberculoides* CARPENTER, 1857

(Text figure 98)

Tablet 2029, 1 juvenile syntype and fragments. [-]. BRANN: plt. 48, fig. 557-b.

This seems to be a color variant and a juvenile shell otherwise identical to *Cerithiopsis tuberculoides*. Carpenter cited no measurements.

159. *Cerithiopsis cerea*, p. 443

= *Cerithiopsis cerea* CARPENTER, 1857

(Text figure 99)

Tablet 2030, holotype. [2.4 mm]. BRANN: plt. 48, fig. 558.

As with other of Carpenter's species of *Cerithiopsis*, BARTSCH (1911 b, p. 333; plt. 37, fig. 6) published the same camera lucida sketch later republished by BRANN, and he reprinted Carpenter's description without comment. It is obvious that he was not able to recognize the species in the material he had available. Carpenter's drawing is distorted as to outline.

160. *Cerithiopsis pupiformis*, p. 443

= *Cerithiopsis pupiformis* CARPENTER, 1857  
(Text figures 100 a-b)

Tablet 2031, 2 syntypes. [1.8 mm]. BRANN: plt. 48, fig. 559.

One wonders whether Carpenter had correctly matched the two specimens he mounted as syntypes, the apex of a juvenile shell and the last few whorls of an adult. Drawn to a common scale, as I have done them, they do not seem to match in contour. The young shell has strong sculpture, the upper of 3 threads being weakest. BARTSCH, as mentioned above, merely reprinted Carpenter's description (*op. cit.*, p. 337; plt. 38, figs. 1, 5).

161. *Cerithiopsis sorex*, p. 444

= ?*Cerithiopsis sorex* CARPENTER, 1857  
(Text figure 101)

Tablet 2032, 1 syntype. [1.6 mm]. BRANN: plt. 49, fig. 560.

Carpenter's drawing does not show, nor does he mention, the slot-like posterior notch, which gives the aperture in the holotype the semblance of a nassariid. I have not found this structure so well developed in actual specimens. One of what appears otherwise to be *Cerithiopsis sorex*, in the Stanford University collection, from near La Paz, Baja California, has a newly-mended outer lip that has not reached its full development; also, the pointed apex is broken off. A species from Panama, *C. eiseni* STRONG & HERTLEIN, (1939, p. 216; plt. 20, fig. 6) seems to have the same contours of the later whorls, but it, too, lacks apical whorls in the figured holotype. Another similar form is *C. perrini* HERTLEIN & STRONG, 1951 (*Zoologica*, vol. 36, no. 5, p. 106; plt. 7, fig. 6) from Port Guatulco, Mexico.

162. *Cerithiopsis tuberculoides*, p. 442

= *Cerithiopsis tuberculoides* CARPENTER, 1857  
(Text figures 102 a-b)

Tablet 2028, 2 syntypes. [1.4 mm; 4 mm]. BRANN: plt. 48, fig. 557.

The younger of the two syntypes was chosen by Carpenter for his drawing. The apex in this has 3 smooth whorls. The adult has a broken aperture; its apex is somewhat imperfect but the remainder of the shell shows the sculpture well, 3 beaded cords per whorl equal in strength.

163. *Cerithiopsis convexa*, p. 444

= *Metaxia convexa* (CARPENTER, 1857)  
(Text figures 103 a-b)

Tablet 2033, holotype. [4.5 mm]. BRANN: plt. 49, fig. 561.

Authors have been able to recognize this species correctly.

164. *Cerithiopsis decussata*, p. 445

= *Bittium decussatum* (CARPENTER, 1857)  
(Text figure 104)

Tablet 2034, holotype. [4 mm]. BRANN: plt. 49, fig. 562.

BARTSCH (1911 c, p. 409; plt. 52, fig. 2) transferred the species to *Bittium*, reprinted Carpenter's description, and published his manuscript drawing. It is evident that Bartsch did not have material at hand.

[Note: Carpenter has been criticized for having bestowed names on fragmentary and unrecognizable material. His usage of *Alaba* as a generic term is especially open to such criticism. Because all but one of the species belong elsewhere and so many are unrecognizable, I have listed all of his named Alabas here, alphabetically instead of systematically. Possibly some of the forms can be matched with fresh material eventually. One can hope that the names will prove useful and do not displace later names based on more complete specimens.]

165. *Alaba alabastrites*, p. 368

?

Tablet 1726, holotype. [1.4 mm]. BRANN: plt. 40, fig. 428.

The holotype is only the apical tip of a shell, the nucleus and 3 whorls of a slender form that could be turrid, columbellid, or rissoinid; therefore, it seems generically and specifically indeterminate.

166. *Alaba conica*, p. 368

?= *Cerithium adustum* KIENER, 1841

Tablet 1728. [2 mm]. BRANN: plt. 40, fig. 430.

The species must be recognized, if it can be at all, from Carpenter's description and drawing and from 3 syntypes in other collections, for the one placed in the British Museum collection is now missing. At some time the end of the vial had broken and the specimen, having come unglued, had lost out. I found no trace of it in the box.

167. ?*Alaba laguncula*, p. 369

?*Iselica* sp.

(Text figure 105)

Tablet 1730, holotype. [1.1 mm]. BRANN: plt. 40, fig. 432.

The specimen consists of the nuclear whorls and part of one spire whorl; the apex seems to be partially immersed or tilted, and as the sculpture suggests *Iselica*, the form may be a pyramidellid. My drawing is only a sketch to show outline and is not to scale.

*Alaba mutans*, p. 369. See no. 122, under Rissoiidae.

168. *Alaba scalata*, p. 368

?*Epitonium* sp., juvenile

(Text figure 107)

Tablet 1727, holotype. [0.9 mm]. BRANN: plt. 43, fig. 429.

The juvenile shell probably is specifically and subgenerically indeterminate.

169. *Alaba supralirata*, p. 366

= *Alaba supralirata* CARPENTER, 1857

Tablet 1723, 3 syntypes. [4.8 mm]. BRANN: plt. 43, fig. 425.

This is Carpenter's only *Alaba* that really qualifies for inclusion. The smallest specimen has 6 whorls, and the apex is well shown in Carpenter's drawing; the middle-sized shell shows the early post-apical sculpture that is portrayed by BARTSCH (1910, pp. 153 - 156, figs. 1 - 2). The largest specimen has obscure sculpture but strong varices, its terminal whorl shown in Carpenter's figure.

Bartsch has quoted E. A. Smith's criticism of Carpenter's overnaming in this genus.

170. *Alaba terebralis*, p. 367

?*Eulima* sp.

(Text figure 108)

Tablet 1725, holotype. [1.7 mm]. BRANN: plt. 40, fig. 427.

The tapering and loosely coiled apex that Carpenter shows now has chipped away to a single whorl that appears obliquely twisted.

171. *Alaba violacea*, p. 367

?*Eulima* sp.

(Text figure 109)

Tablet 1724, holotype. [1.5 mm]. BRANN: plt. 40, fig. 426.

The shell is broken and one must guess at the true outline.

172. *Alvania effusa*, p. 359

= *Alabina effusa* (CARPENTER, 1857)

(Text figure 110)

Tablet 1710, holotype. [3 mm]. BRANN: plt. 39, fig. 413.

BARTSCH (1911 d, p. 358; plt. 32, fig. 5), reproduced Carpenter's drawing and continued this in *Alvania* rather than *Alabina*, which he also reviewed (1911 a). It seems to me to have all the characters of *Alabina*, for no other *Alvania* is so slender and tall.

173. ?*Alvania excurvata*, p. 359

= *Alabina excurvata* (CARPENTER, 1857)

(Text figure 111)

Tablet 1709, 8 syntypes. [3 mm]. BRANN: plt. 39, fig. 412.

This is a prior name for *Alabina diomedae* BARTSCH, 1911 (1911 a, p. 413; plt. 62, fig. 1), an abundant small mollusk in the Gulf of California. One wonders that Bartsch failed to recognize the form from the Carpenter drawing, which he had available. Under the Article 23(b)

of the International Code of Zoological Nomenclature, Bartsch's specific name might be declared a *nomen oblitum*, for it has been a junior synonym more than the requisite 50 years, but at present the International Commission is at an impasse on the proper procedure for implementing this rule.

#### POTAMIDIDAE

174. *Cerithidea* ?*varicosa* SOWERBY, var. *mazatlanica*, p. 344

= *Cerithidea mazatlanica* CARPENTER, 1857  
(Plate 57, Figures 47 a-d)

Tablets 1628 - 1637, 33 syntypes (4 on tablet 1630 figured). [25 mm].

Authors have had no problems with the identification of this form. A specimen from the Cuming collection was figured by Sowerby in REEVE, 1866 (Conch. Icon., vol. 15, *Cerithidea*, plt. 1, sp. 8).

#### HIPPONICIDAE

175. *Hipponyx serratus*, "n. s.", p. 296

= *Hipponix serratus* (CARPENTER, 1856)

(Plate 57, Figures 43 a-b)

Tablets 1462 - 1468, 12 syntypes. [25 mm]. BRANN: plt. 31, fig. 346.

Two syntypes on tablet 1465 are figured here. The species name was validated earlier (CARPENTER, 1856 b, p. 3) based on other British Museum as well as Reigen material.

176. *Hipponyx planatus*, p. 298

= *Hipponix planatus* (CARPENTER, 1857)

(Plate 57, Figures 42 a-b; Text figures 112 a-b)

Tablet 1470, 2 syntypes. [1.5 mm - 5 mm]. BRANN: plt. 31, fig. 348.

The Mazatlan material consisted of immature specimens. One lot of adult shells from Panama (Cuming collection) was also cited; it is now in the Type Collection, British Museum, registry no. 1966625. [19 mm].

#### FOSSARIDAE

177. *Fossarus angulatus*, p. 354

= *Fossarus angulatus* CARPENTER, 1857

Tablet 1701, 1 syntype. [1.8 mm]. BRANN: plt. 38, fig. 405.

The syntype originally retained at the British Museum is now almost entirely disintegrated; there appear to have been 2 carinae, a wide columellar lip, and a large aperture with a thickened rim, but Carpenter's drawing is the only real clue to identity.

178. *Fossarus tuberosus*, p. 354

= *Fossarus tuberosus* CARPENTER, 1857  
(Text figure 113)

Tablet 1700, 2 syntypes. [1.1 mm]. BRANN: plt. 38, fig. 404.

Carpenter's drawing should enable the identification of this form. The smaller syntype shows 2 brown nuclear whorls and 4 carinae on the body whorl; the larger has 3 brown nuclear whorls and fine spiral intercalary ribs.

## CALYPTRAEIDAE

179. *Trochita ventricosa*, p. 264

= *Calyptraea (Trochita) spirata ventricosa* (CARPENTER, 1857)

(Plate 57, Figures 55 a-b)

Tablet 1316, holotype. [19 mm].

The holotype is glued to the mount at an angle difficult for proper photography.

## CREPIDULIDAE

180. *Crepidula ?dorsata* Brod., var. *bilobata*, p. 273

= *Crepidula aculeata* (GMELIN, 1791)

(Plate 57, Figure 56; Text figure 114)

Tablet 1354, 5 syntypes. [9.5 mm]. BRANN: plt. 28, fig. 336.

Carpenter's drawings are of the 4 smallest syntypes. My photograph shows the exterior of the largest. Although covered by an incrustation, it shows a pattern of large and small spines as in *Crepidula aculeata*. Carpenter describes the deck as brown; perhaps it was, in fresh material, but to my eyes it is now white. All the specimens were immature. Possibly the name may have some use if a brown-decked variant of *C. aculeata* comes to light.

## MURICIDAE

181. *Murex ?recurvirostris lividus*, p. 519

= *Murex (Murex) lividus* CARPENTER, 1857  
(Plate 58, Figures 63 a-b)

Tablets 2467 - 2480, 23 syntypes (specimens from tablet 2477 here figured). [52 mm].

This form seems to be morphologically distinct from *Murex recurvirostris* BRODERIP, 1833, in which spines are obsolescent, and *M. elenensis* DALL, 1919, in which they are numerous. In *M. lividus* spines are sparsely present on spire and canal.

182. *Muricidea ?erinaceoides*, var. *indentata*, p. 527

= *Aspella indentata* (CARPENTER, 1857)  
(Plate 58, Figure 64)

Tablet 2510, holotype. [34 mm].

A few months after describing *Aspella perplexa* KEEN, 1958, I had opportunity to see Carpenter's holotype and – perhaps too hastily – decided my species must fall as a synonym. Now with a photograph of the type and more Mexican material, I suspect our *Aspellas* all need re-study.

## COLUMBELLIDAE

183. *Anachis albonodosa*, p. 512

= *Anachis albonodosa* CARPENTER, 1857  
(Plate 59, Figure 82)

Tablet 2432, syntype. [3.3 mm]. BRANN: plt. 56, fig. 654.

Axial sculpture begins on the fourth whorl of the otherwise smooth spire and fades out on the base of the body whorl; the ribs are smooth and end above in white nodes. The aperture is contracted and the outer lip thin, perhaps immature. I have not as yet found among the numerous available specimens of *Anachis* of the West Mexican area in collections I have studied one that I could positively identify as *A. albonodosa*. Perhaps now that figures are published, collectors may be able to recognize the form.

184. *Anachis gaskoini*, p. 510

= *Anachis gaskoini* CARPENTER, 1857  
(Plate 59, Figure 86; Text figure 115)

Tablet 2430 (sketch). [6 mm].

This form was described by PHILIPPI in 1846 as *Columbella taeniata*, a name preoccupied by *C. taeniata* LINK, 1807. Before Carpenter had accidentally smashed the type specimen of a Mazatlan form his friend Gaskoin had pronounced a new species, he had made a sketch, which is reproduced in facsimile here. Although poor, it is recognizable as the *C. taeniata* PHILIPPI of authors and is reinforced both by Carpenter's label on a specimen in the British Museum collection from Callao, Peru, registry number 79.2.26.109 (see Plate 59, Figure 86) and by his synonymizing of the two names later (CARPENTER, 1865 b, p. 273). DALL in 1918 named *Anachis bartschii*, which has remained unfigured, but photographs of the type lot show it to be identical to Carpenter's species. BAKER, HANNA, & STRONG (1938, Proc. Calif. Acad. Sci., ser. 4, vol. 23, no. 16, p. 249; plt. 24, fig. 11), working from the description alone, figured a specimen as *A. bartschii* that is a yet-undescribed species. Unfortunately,

I copied their figure (KEEN, 1958, fig. 421). GRANT & GALE (1931, p. 688; plt. 26, fig. 47) attempted to illustrate *A. gaskoini*, but their figure turns out to be of a variant that also is unnamed. Again – unfortunately – I copied the figure (KEEN, 1958, fig. 433). I plan a review of some of these West Coast Columbellidae to clarify the nomenclature. The true *A. gaskoini* is white, with golden-brown spiral lines and a few dark brown dots. The species is not uncommon but up to now has not been adequately illustrated.

185. *Anachis nigrofusca*, p. 509

= *Anachis nigrofusca* CARPENTER, 1857

Tablet 2427, 2 syntypes. [10 mm].

Authors have identified this species correctly. The syntypes show spiral striae between axial ribs more distinctly than in the specimen figured in KEEN, 1958 (p. 383; fig. 445) but the identity is obvious.

186. *Anachis* ?*costellata*, var. *pachyderma*, p. 507

?= *Anachis scalarina* (SOWERBY, 1832)

(Plate 59, Figures 83 a-b)

Tablets 2422 - 2423, 7 syntypes. [17 mm]. BRANN: plt. 56, fig. [646 b] (operculum).

Carpenter described this as a variant of *Anachis costellata*, but it seems closer to *A. scalarina*; perhaps this northern form may prove subspecifically distinct because of the periostracum and smaller size.

187. *Anachis rufotincta*, p. 511

= *Anachis diminuta* (C. B. ADAMS, 1852)

Tablet 2431, 3 syntypes. [3.5 mm]. BRANN: plt. 56, fig. 653.

Looking at the type material my judgment was that these were only faded specimens of *Anachis diminuta*, a wide-ranging Panamic species.

188. *Anachis serrata*, p. 509

= *Anachis* (?*Glyptanachis*) *serrata* CARPENTER, 1857

(Plate 59, Figures 87; Text figure 116)

Tablet 2428, 3 syntypes, all juvenile, the largest here selected as lectotype. [3.3 mm]. BRANN: plt. 56, fig. 650.

The two fragments on the tablet, mentioned by Carpenter, are of other species, and only the 3 specimens at the left are of this form. The relationships are still in doubt, for it may prove to be a *Nassarina* rather than an *Anachis*. I plan further work on the West American columbellids.

189. *Columbella cervinetta*, p. 493

= *Mitrella baccata* (GASKOIN, 1852)

(Plate 59, Figure 84)

Tablet 2360, holotype. [6.9 mm]. BRANN: plt. 55, fig. 618.

Carpenter was evidently unfamiliar with Gaskoin's species. His figure shows well the axial ribbing on the

spire that distinguishes this and another as-yet-unnamed Gulf *Mitrella*.

190. *Columbella cervinetta obsoleta*, p. 493

= *Mitrella baccata* (GASKOIN, 1852)

(Plate 59, Figure 85)

Tablet 2361, syntype. [-]. BRANN: plt. 55, fig. 618-b.

I can see no reason for separating this form, merely a worn and faded shell.

## BUCCINIDAE

191. *Fusus apertus*, p. 504

?= *Cantharus biliratus* (REEVE, 1846)

(Text figure 117)

Tablet 2414, 3 incomplete syntypes. [2.5 mm]. BRANN: plt. 53, fig. 641.

The best specimen shows 4 brown bands and nodose sculpture, suggesting young *Cantharus*. Specimens of *C. biliratus* from Guaymas, collected by D. R. Shasky, match it well as to details of apical sculpture.

192. *Pisania aequilirata*, p. 515

= *Cantharus elegans* (GRIFFITH & PIDGEON, 1834)

(Plate 59, Figure 90)

Tablet 2451, holotype. [25 mm].

Authors have correctly recognized this from Carpenter's description.

## NASSARIIDAE

193. *Nassa pagodus*, var. *acuta*, p. 497 [non SAY, 1822]

?= *Nassarius pagodus* (REEVE, 1846), ?n. subsp.

(Plate 58, Figure 61)

Tablet 2394, 1 syntype. [21.5 mm].

The shell has finer spiral sculpture than typical *Nassarius pagodus*, and the axial ribs are fewer. If this is consistent, perhaps the form may have validity as a subspecies, but a new name will be required, Carpenter's having been preoccupied.

194. *Nassa crebristriata*, p. 499

= *Nassarius versicolor* (C. B. ADAMS, 1852)

(Plate 58, Figure 60)

Tablet 2402, holotype. [13.8 mm].

This seems to be a slender form of the variable *Nassarius versicolor*.

195. *Nassa ?tegula*, var. *nodulifera*, p. 496

ex PHILIPPI, MS

= *Nassarius luteostoma* (BRODERIP & SOWERBY, 1829)

(Plate 58, Figure 59)

Tablet 2393, holotype. [16.2 mm].

As Carpenter suspected, this is a needless name.

## FUSINIDAE

(?)

196. *Fusus tumens*, p. 503=?*Fusinus cinereus* (REEVE, 1847)

(Text figure 118)

Tablet 2413, 2 syntypes. [4 mm]. BRANN: plt. 53, fig. 640.

The shell is whitish, banded at the suture and on the base with brown. It appears to be a juvenile *Fusinus*.

## OLIVIDAE

197. *Oliva intertincta*, p. 465=*Oliva spicata* RÖDING, 1798

(Plate 58, Figure 57)

Tablet 2121, 3 syntypes. [20 mm].

The two larger syntypes are in good condition; the smallest is partially decorticated.

198. *Olivella* ?*petiolita*, var. *aureocincta*, p. 470=*Olivella aureocincta* CARPENTER, 1857

(Plate 59, Figures 88 a-b)

Tablet 2186, 8 syntypes. [9.5 mm].

All of these syntypes are beginning to show deterioration of the surface layer, but neatsfoot oil restores to some extent the color pattern, especially in the best-preserved two that are figured here. The shell is near *Olivella dama* (WOOD, 1828) in outline but of smaller size. The color pattern is undulating to zigzag. When the shells were fresh, according to Carpenter's description, there were two spiral color bands of a golden hue. This form probably is the basis for the records of the Caribbean *O. petiolita* (DUCLOS, 1835) in the tropical West American fauna.

## MARGINELLIDAE

199. *Marginella margaritula*, p. 462=*Cypraeolina margaritula* (CARPENTER, 1857)

(Text figure 119)

Tablet 2109, 7 syntypes (2 adult). [1.8 mm]. BRANN: plt. 49, fig. 589.

The larger adult specimen was chosen as lectotype by COAN &amp; ROTH (1966, The Veliger, vol. 8, no. 4, p. 294).

200. *Marginella polita*, p. 462=*Kogomea polita* (CARPENTER, 1857)

Text figures 120 a-c

Tablet 2108, 3 syntypes. [0.8 mm]. BRANN: plt. 49, fig. 588.

COAN &amp; ROTH (1966, The Veliger, vol. 8, no. 4, p. 293) have selected the largest specimen as lectotype.

## TURRIDAE

201. *Drillia albonodosa*, p. 397=*Crassispira albonodosa* (CARPENTER, 1857)

(Plate 59, Figure 100)

Tablet 1901, 1 syntype (here chosen as lectotype). [13 mm].

This seems to be a distinct species. It comes closest to *Clathrodrillia jaculum* (PILSBRY & LOWE, 1932) as to sculpture and outline, but its sooty color puts it in *Crassispira*.

202. *Drillia albovallosa*, p. 396=*Crassispira rudis* (SOWERBY, 1834)

(Plate 59, Figure 98)

Tablet 1900, holotype. [10.8 mm].

Someone (probably E. A. Smith, possibly J. R. leB. Tomlin) has put the notation, "*D. rudis*, jun." on the tablet. A juvenile topotype specimen of the latter in the Stanford University collection matches well my photograph of Carpenter's type; so also does a juvenile specimen from Mazatlan. Adults show a greater convexity of outline near the base of the body whorl that changes the appearance, and this probably influenced Carpenter in his decision that the form was distinct.

203. *Drillia cerithioidea*, p. 394=*Crassispira cerithioidea* (CARPENTER, 1857)

(Plate 58, Figure 77; Text figure 121)

Tablet 1897, 1 syntype. [16 mm].

This may be a prior name for the *Crassispira pluto* PILSBRY & LOWE, 1932. Comparison of material collected and identified by Lowe with Carpenter's type showed only minor differences, such as slightly coarser nodes on the spire of *C. pluto* in some specimens.

204. *Drillia hanleyi*, p. 398=*Crassispira hanleyi* (CARPENTER, 1857)

(Plate 59, Figure 99)

Tablet 1907, holotype. [9.8 mm].

This seems to be distinct. Although close to *Crassispira ericana* HERTLEIN & STRONG, 1951, it is proportionately wider and shorter.

205. *Drillia aterrima*, var. *melchersi* (MENKE, 1851), p. 393=*Crassispira aterrima* (SOWERBY, 1834)

Tablets 1891 - 1896. [18 mm].

Although he used the same format that he did for proposal of new varieties, Carpenter included in his synonymy a reference to Menke's proposal of the name. The name is available for subdivision of the somewhat

variable *Crassispira aterrima*, but Menke's type would need study.

206. *Drillia monilifera*, p. 395  
 = *Crassispira monilifera* (CARPENTER, 1857)  
 (Plate 58, Figure 76)

Tablet 1899, holotype. [16.4 mm].

*Crassispira nymphia* PILSBRY & LOWE, 1932, is very close to this. Comparison of specimens collected and identified by Lowe with Carpenter's type showed only that the peripheral nodes in *C. nymphia* are coarser and fewer. The nodes are yellow-orange, and the spiral threads on the pillar beaded with yellow.

207. *Mangelia sulcata* CARPENTER, 1865 b, p. 272  
 = *Mangelia (Kurtzina) sulcata* CARPENTER, 1865  
 (Text figure 122)

Tablet 2538, holotype. [5 mm]. BRANN: plt. 41, fig. 702.

The shell resembles *Mangelia (Kurtzina) cymatias* PILSBRY & LOWE, 1932, but the axial ribs are wider; the upper part of the whorls shows a faint brown band.

208. *Mangelia ?acuticostata*, var. *subangulata*, p. 400  
 = *Mangelia (Kurtzina) subangulata* (CARPENTER, 1857)

(Plate 58, Figure 62; Text figure 123)

Tablet 1914, holotype. [3.5 mm]. BRANN: plt. 41, fig. 473.

This also resembles *Mangelia (Kurtzina) cymatias* PILSBRY & LOWE but has one more axial rib per whorl. The axial ribs are more sinuous, and there are faint spirals showing between them. The anterior canal of the holotype is a little broken. There is a discrepancy of nearly a millimeter between my measurement of length and Carpenter's.

209. *Clathurella aurea*, p. 400  
 = *Clathurella aurea* CARPENTER, 1857  
 (Plate 58, Figure 74; Text figure 124)

Tablet 1913, holotype. [15.8 mm].

The nodes on the spiral ribs are more elongate than in *Clathurella (Lioglyphostoma) armstrongi* HERTLEIN & STRONG, 1955, which otherwise has a strong resemblance to Carpenter's species. The outer lip is denticulate within; one wonders whether this is a reliable character for differentiating between *Clathurella* s. s. and *Lioglyphostoma*. The outline of this and other West Coast turrids now classed as *Lioglyphostoma* is closer to that of the type of *Glyphostomops* BARTSCH, 1934, from deep water in the Caribbean than to the type of *Lioglyphostoma*, also Caribbean.

# TEREBRIDAE

210. *Terebra (Myurella) albocincta*, p. 384  
 = *Terebra variegata* GRAY, 1834  
 (Plate 58, Figure 70)

Tablets 1828 - 1835, 23 syntypes (tablet 1828 photographed). [41 mm].

A note on the back of the mount, by G. K. Robson says, "Designated type by me for Dr. Bartsch, 25/5/23," but neither Robson nor Bartsch published a lectotype selection. CAMPBELL (1964, p. 137) has concluded, on the basis of supposed paratype and of topotype material, that this form is not separable from the widely distributed *Terebra variegata*. The type lot supports his judgment; Carpenter, however, felt that *T. armillata* HINDS was closer.

211. *Terebra (Myurella) hindsii*, p. 385  
 = *Terebra variegata* GRAY, 1834  
 (Plate 58, Figures 71 a-b)

Tablet 1836, 2 syntypes. [32 mm].

As the photograph here given of the type material supports the conclusion by CAMPBELL (1964, p. 137), we must synonymize this as part of the *Terebra variegata* complex. It is not the form from the outer coast of Baja California identified as *T. hindsii* by GRANT & GALE (1931, p. 469), which is now to be known as *T. tiarella* DESHAYES, 1857. Therefore, figures 955 and 964 in KEEN, 1958, are incorrectly captioned.

212. *Terebra (Myurella) rufocinerea*, p. 386  
 = *Terebra variegata* GRAY, 1834  
 (Plate 58, Figure 73)

Tablet 1838, 2 syntypes. [32 mm].

This, too, seems indistinguishable from *Terebra variegata*. It is a form with the axial ribs slightly stronger and straighter.

213. *Terebra (Myurella) subnodosa*, p. 386  
 = *Terebra intertincta* HINDS, 1844  
 (Plate 58, Figure 72)

Tablet 1837, 1 syntype. [32 mm].

Although, following authors, I synonymized this with *Terebra albocincta* (see KEEN, 1958, p. 490), the photograph of the syntype shows a more stubby shell with decided nodes on the base, a hallmark of the species *T. intertincta*. Carpenter's specific name has one month's priority over *T. marginata* DESHAYES, 1857.

## BULLIDAE

214. *Haminea cymbiformis*, p. 174

= *Haminea cymbiformis* CARPENTER, 1857  
(Text figure 125)

Tablet 793, holotype. [1.8 mm]. BRANN: plt. 19, fig. 229.

Carpenter's restoration of the outline for the broken outer lip in this minute juvenile shell differs somewhat from mine. The apex is a shallow pit; there are fine and somewhat sinuate growth lines. The shell is thin and greenish-yellow in color.

215. *Bulla exarata*, p. 173

= *Atys exarata* (CARPENTER, 1857)  
(Text figure 126)

Tablet 791, 1 syntype. [3.2 mm]. BRANN: plt. 19, fig. 227.

Carpenter's drawing does not show the irregular break in the front of the body whorl. The shell is brown, but this may be a stain. The columellar lip has no umbilical chink and no fold. There are 4 thin brown punctate spiral lines near the apex, a smooth band below this, then two wider lines, with 10 somewhat more close-set lines toward the base. Though near *Atys chimera* BAKER & HANNA, 1927, this may prove to be a good species.

## JULIIDAE

216. *Smaragdinella thecaphora*, p. 533

= *Julia thecaphora* (CARPENTER, 1857)  
(Text figure 127)

Tablet 2527, holotype. [2 mm]. BRANN: plt. 18, fig. 692.

OLSSON, 1961 (Panama-Pacific Pelecypoda, p. 142) has pointed out that Carpenter's name has priority over *Julia equatorialis* PILSBRY & OLSSON, 1944. I suspect that the supposed *J. exquisita* GOULD, 1862, reported by A. D. Howard from Baja California also is this species.

## ACTEOCINIDAE

217. *Tornatina carinata*, p. 171

= *Acteocina carinata* (CARPENTER, 1857)  
(Text figure 128)

Tablet 784, 5 syntypes. [2.8 mm]. BRANN: plt. 19, fig. 223.

Carpenter's drawing does not show a hole in the body whorl made by a carnivorous snail. The adult, shown both in Carpenter's drawing and mine, does not exhibit as clearly as do the younger syntypes the double ridge on the spire that is characteristic of the species; the young are relatively shorter and lower spired.

## PYRAMIDELLIDAE

In the introduction to their comprehensive review of West American Pyramidellidae, DALL & BARTSCH (1909, p. 2) state that Bartsch had opportunity while in Britain to study Carpenter's Mazatlan types. I shall therefore rely upon their allocations for these species. They also had available and used as figures some of the manuscript drawings that have now been published in full by BRANN (1966). I shall cite BRANN's plates rather than the earlier version of DALL & BARTSCH. Carpenter cited the generic names in his introduction to the discussion of the family but in the body of the text combined the specific names with subgeneric names. Brann correctly lists the generic and specific combination, but Dall and Bartsch utilize the subgeneric-specific name combination. When Carpenter's allocation is in complete agreement with that of Dall and Bartsch, I shall, to save space and avoid repetition, abbreviate generic and subgeneric names to the initial letters.

218. *Odostomia lamellata*, p. 411

?= *Pyramidella* (*Longchaeus*) *mazatlanica* DALL & BARTSCH, 1909

(Text figure 129)

Tablet 1954, 2 fragments. [2.5 mm]. BRANN: plt. 42, fig. 489.

DALL & BARTSCH (1909, p. 24) cite this form as of uncertain standing and suggest that it may be the young of their new species. Even the larger fragment is too broken for positive determination.

219. *Odostomia subsulcata*, p. 411

?*Pyramidella* (*Longchaeus*) sp.

(Text figure 130)

Tablet 1955, 2 syntypes. [1.1 mm]. BRANN: plt. 43, fig. 490.

I can add nothing to Bartsch's comment that the specimens are too young and worn for specific determination.

220. *Odostomia vallata*, p. 411

*Pyramidella* (*Longchaeus*) sp.

(Text figure 131)

Tablet 1956, 3 syntypes. [1.4 mm]. BRANN: plt. 43, fig. 491.

According to my notes, my drawing is of the best of the 3 specimens and there is only a faint carina. Carpenter's drawing shows a strong one. In any case, the shell seems to be unidentifiable; it is juvenile.

221. *Odostomia (Chrysallida) convexa*, p. 424  
 = *Odostomia (Besla) convexa* CARPENTER, 1857  
 (Text figure 132)

Tablet 1984, 1 syntype. [2 mm]. BRANN: plt. 45, fig. 514.

This species is type of the subgenus *Besla* DALL & BARTSCH, 1904.

222. *Odostomia (Chrysallida) effusa* p. 422  
 = *O. (C.) effusa* CARPENTER, 1857  
 (Text figure 133)

Tablet 1980, holotype. [2.2 mm]. BRANN: plt. 45, fig. 510.

A supposed younger specimen glued to the tablet by Carpenter seems to be an *Alvania*, cf. *A. tumida* CARPENTER. I regard the larger shell as a holotype because Carpenter cites it as "the specimen."

223. *Odostomia (Chrysallida) fasciata*, p. 423  
 = *O. (C.) fasciata* CARPENTER, 1857  
 (Text figure 134)

Tablet 1981, 5 syntypes. [2.1 mm]. BRANN: plt. 45, fig. 511.

The interspaces appear to be punctate, and the nodes on the spire are well developed.

224. *Odostomia (Chrysallida) nodosa*, p. 417  
 = *O. (C.) nodosa* CARPENTER, 1857  
 (Text figure 135)

Tablet 1969, 2 syntypes. [4.1 mm]. BRANN: plt. 44, fig. 504.

One of the syntypes is juvenile.

225. *Odostomia (Chrysallida) oblonga* CARPENTER, 1857, p. 418 (non MACGILLIVRAY, 1848)  
 = *O. (C.) benthina* DALL & BARTSCH, 1909, new name  
 (Text figure 136)

Tablet 1971, 2 syntypes. [3.8 mm]. BRANN: plt. 44, fig. 506.

One of the syntypes is juvenile.

226. *Odostomia (Chrysallida) ovata*, p. 417  
 = *O. (C.) ovata* CARPENTER, 1857  
 (Text figure 137)

Tablet 1968, 3 syntypes. [3.8 mm]. BRANN: plt. 44, fig. 503.

227. *Odostomia (Chrysallida) ovulum*, p. 423 (non *Parthenia ovulum* LEA, 1845)  
 = *O. (C.) oonisca* DALL & BARTSCH, 1909, new name  
 (Text figure 138)

Tablet 1982, 9 syntypes. [1.4 mm]. BRANN: plt. 45, fig. 512.

The sculpture is nodose, the basal furrows crenulate.

BRANN, p. 70, erroneously records the replacement name as *Odostomia benthina*.

228. *Odostomia (Chrysallida) reigeni*, p. 422  
 = *O. (C.) reigeni* CARPENTER, 1857  
 (Text figure 139)

Tablet 1979, holotype. [1.4 mm]. BRANN: plt. 44, fig. 509.

229. *Odostomia (Chrysallida) rotundata* p. 418  
 = *O. (C.) rotundata* CARPENTER, 1857  
 (Text figure 140)

Tablet 1970, 3 syntypes. [2.2 mm]. BRANN: plt. 44, fig. 505.

230. *Odostomia (Chrysallida) telescopium*, p. 421  
 = *O. (C.) telescopium* CARPENTER, 1857  
 (Text figure 141)

Tablet 1978, 4 syntypes. [3.2 mm]. BRANN: plt. 44, fig. 508.

231. *Odostomia (Parthenia) lacunata*, p. 414  
 = *Odostomia (Egila) lacunata* CARPENTER, 1857  
 (Text figure 142)

Tablet 1964, 1 syntype. [1 mm]. BRANN: plt. 43, fig. 499.

232. *Odostomia (Odostomia) tenuis*, p. 412  
 = *Odostomia (Evalea) tenuis* CARPENTER, 1857  
 (Text figure 143)

Tablet 1958, 1 syntype. [1.6 mm]. BRANN: plt. 43, fig. 493.

The columellar plait can be seen only faintly by tilting the shell.

233. *Chemnitzia (Dunkeria) intermedia*, p. 435  
 = *Odostomia (Evalina) intermedia* (CARPENTER, 1857)  
 (Text figure 144)

Tablet 2010, 1 syntype. [1.4 mm]. BRANN: plt. 45, fig. 539.

The sculpture is entirely spiral except for some wrinkles below the suture.

234. *Odostomia (Chrysallida) photis*, p. 425  
 = *Odostomia (Haldra) photis* CARPENTER, 1857  
 (Text figure 145)

Tablet 1985, 1 syntype. [1.2 mm]. BRANN: plt. 45, fig. 515.

235. *Odostomia (Parthenia) quinquecincta*, p. 414  
 = *Odostomia (Ividella) quinquecincta* CARPENTER, 1857  
 (Text figure 146)

Tablet 1963, 1 syntype. [1.6 mm]. BRANN: plt. 43, fig. 498.

236. *Odostomia* (?*Chrysallida*) *clausiliformis*, p. 426  
 = *Odostomia* (*Lysacme*) *clausiliformis* CARPENTER, 1857

(Text figure 147)

Tablet 1987, 1 syntype. [3.8 mm]. BRANN: plt. 45, fig. 517.

There is a suggestion of basal cords. The shell is decorated, with a broken outer lip. The mounted operculum (if it is one) could hardly have come from so worn a shell.

237. *Odostomia* (*Odostomia*) *sublirulata*, p. 410  
 = *Odostomia* (*Menestho*) *sublirulata* CARPENTER, 1857  
 (Text figure 148)

Tablet 1952, holotype. [2 mm]. BRANN: plt. 42, fig. 487.  
 Lirations on the body whorl of the type are faint.

238. *Odostomia* (*Parthenia*) *ziziphina*, p. 416  
 = *Odostomia* (*Menestho*) *ziziphina* CARPENTER, 1857  
 (Text figure 149)

Tablet 1967, holotype. [0.7 mm]. BRANN: plt. 43, fig. 502.

239. *Odostomia* (*Parthenia*) *armata*, p. 415  
 = *Odostomia* (*Miralda*) *armata* CARPENTER, 1857  
 (Text figure 150)

Tablet 1965, 1 syntype. [2.5 mm]. BRANN: plt. 43, fig. 500.

The shell cannot be oriented in a normal position for drawing or photographing without removal from the mount, which I did not attempt.

240. *Odostomia* (*Parthenia*) *exarata*, p. 415  
 = *Odostomia* (*Miralda*) *exarata* CARPENTER, 1857  
 (Text figure 151)

Tablet 1966, 1 hypotype. [2.2 mm]. BRANN: plt. 42, fig. 501, holotype ["6.3 mm."].

Carpenter's description was prepared from the specimen figured in his drawing. Later he stated (1865 b, p. 274) that he had substituted a much finer shell, which is the one shown in my figure. Only a glue smear remains on the slide to show where the original (holotype) had been, and he did not indicate what had been done with it. Perhaps it may be the specimen reported by PALMER (1951, p. 55) at McGill University (Redpath Museum), or it may be in one of the other institutions holding Carpenterian material. Evidently his stated dimensions are in error – length, 6.3, width 0.8 mm – for this is at variance with his words, "stout little shell." I measure the hypotype as length 2.7 mm, width 1.8 mm, which is more in accord with his diagnosis.

241. *Odostomia* (*Odostomia*) *mammillata*, p. 412  
 = *O. (O.) mammillata* CARPENTER, 1857  
 (Text figure 152)

Tablet 1957, holotype. [1.1 mm]. BRANN: plt. 43, fig. 492.

The columellar fold, somewhat obscured by sand grains, is small but present. Later, CARPENTER (1865 b, p. 272) thought the form might be *Diala paupercula* (C. B. ADAMS, 1852), but DALL & BARTSCH (1909, p. 233) restored it to *Odostomia* without comment.

242. *Odostomia* (*Parthenia*) *scalariformis*, p. 413  
 = *Odostomia* (*Salassia*) *scalariformis* CARPENTER, 1857  
 (Text figure 153)

Tablet 1962, 1 syntype. [2.5 mm]. BRANN: plt. 42, fig. 497.

DALL & BARTSCH (1909, p. 135) cite the length as 5 mm. BAKER, HANNA, & STRONG (1928, p. 227), on the basis of a California Academy specimen, state it as 2.5 mm. I measured the British Museum syntype as 2.7 mm, using a vernier caliper, as 3.0 mm with the camera lucida. In any case, the type is well under 5 mm in length.

243. *Fossarus* (*Isapis*) *maculosa*, p. 355  
 = *Iselica maculosa* (CARPENTER, 1857)  
 (Text figure 154)

Tablet 1702, 2 syntypes. [3 mm]. BRANN: plt. 39, fig. 406.

The apex of the larger syntype is white, flattened, apparently heterostrophic. The smaller syntype is so deteriorated as to be unrecognizable.

244. *Chemnitzia* (*Chemnitzia*) *muricata*, p. 428  
 = *Turbonilla* (*Chemnitzia*) *muricata* (CARPENTER, 1857)  
 (Text figure 155)

Tablet 1993, 2 syntypes. [2.2 mm]. BRANN: plt. 46, fig. 522.

245. *Chemnitzia* (*Dunkeria*) *subangulata*, p. 434  
 = *Turbonilla* (*Bartschella*) *subangulata* (CARPENTER, 1857)  
 (Text figure 156)

Tablet 2008, 2 syntypes (one juvenile). [2.8 mm]. BRANN: plt. 47, fig. 537.

246. *Chemnitzia* (*Dunkeria*) *cancellata*, p. 435 (*non* ORBIGNY, 1842)  
 = *Turbonilla* (*Dunkeria*) sp.  
 (Text figure 157)

Tablet 2009, holotype (juvenile). [1 mm]. BRANN: plt. 45, fig. 538.

Dall and Bartsch failed to catch this homonymy because they had cited the species under the subgeneric rather than the generic name. It is doubtful whether the form can be recognized from so young a type. In any case, the homonym should not be renamed but rather a new species described, based on adult material, should growth series become available that would link Carpenter's type with adult specimens in need of a name.

247. *Chemnitzia (Dunkeria) paucilirata*, p. 434  
= *Turbonilla (Dunkeria) paucilirata* (CARPENTER, 1857)

(Text figure 158)

Tablet 2007, holotype. [2.1 mm]. BRANN: plt. 47, fig. 536.

The specimen is, as Carpenter's drawing shows, broken and worn. It may, however, be recognizable.

248. ?*Eulimella obsoleta*, p. 436  
= *Turbonilla (Ptycheulimella) obsoleta* (CARPENTER, 1857)

(Text figure 159)

Tablet 2011, holotype. [1.5 mm]. BRANN: plt. 47, fig. 540.

The specimen is worn smooth, the apex gone, the aperture incomplete. I question whether it is recognizable, although Dall and Bartsch seemed confident as to its allocation.

249. *Chemnitzia flavescens*, p. 432  
= *Turbonilla (Pyrgiscus) flavescens* (CARPENTER, 1857)  
(Text figure 160)

Tablet 2003, holotype. [2.8 mm]. BRANN: plt. 46, fig. 532.

Spiral threads are minute, the axial ribs sinuous. The anterior part of the aperture in the type is broken, as Carpenter's drawing shows.

250. *Chemnitzia gracillima*, p. 431  
= *Turbonilla (Pyrgiscus) gracillima* (CARPENTER, 1857)

(Text figure 161)

Tablet 2001, 1 syntype. [2.8 mm]. BRANN: plt. 46, fig. 530.

251. *Odostomia (Chrysallida) indentata*, p. 425  
= *Turbonilla (Pyrgiscus) indentata* (CARPENTER, 1857)

(Text figure 162)

Tablet 1986, 1 syntype. [4 mm]. BRANN: plt. 45, fig. 516.

The shell is brown, not white, its interspaces with fine spiral threads. The allocation of Dall and Bartsch to *Turbonilla* seems justified.

252. *Chemnitzia tenuilirata*, p. 433  
= *Turbonilla (Pyrgiscus) tenuilirata* (CARPENTER, 1857)

(Text figures 163 a-b)

Tablet 2005, 2 syntypes. [1.6 mm]. BRANN: plt. 47, fig. 534.

DALL & BARTSCH (1909) did not cite this form and apparently regarded it as a synonym of *Turbonilla tenuicula* (see discussion under the next species). The axial ribs are prominent, the spirals obsolete on the upper part of the whorls.

253. *Chemnitzia terebralis*, p. 432  
= *Turbonilla (Pyrgiscus) terebralis* (CARPENTER, 1857)  
(Text figure 164)

Tablet 2004, holotype. [2.4 mm]. BRANN: plt. 46, fig. 533.

DALL & BARTSCH (1909, p. 92) place this in the synonymy of the California species *Turbonilla (Pyrgiscus) tenuicula* (GOULD, 1853), a variable form, which they do not otherwise cite as from Gulf of California localities. Until this form can be shown definitely to range south of Baja California, it seems best to regard *T. terebralis* and the closely related *T. tenuilirata* and *T. unifasciata* either as separate species or as only subspecifically distinct from each other. In *T. terebralis* the intersections of the fine spiral and distinct axial ribs are well marked, almost beaded.

254. *Chemnitzia unifasciata*, p. 433  
= *Turbonilla (Pyrgiscus) unifasciata* (CARPENTER, 1857)

(Text figure 165)

Tablet 2006, holotype. [2.3 mm]. BRANN: plt. 47, fig. 535.

The outer lip of the holotype is broken, the shell worn and polished by abrasion. A yellow color band shows through the shell; spiral sculpture is faint. (See discussion under the two entries above).

255. *Chemnitzia c-b-adamsii*, p. 427  
= *Turbonilla (Strioturbonilla) c-b-adamsii* (CARPENTER, 1857)

(Text figure 166)

Tablet 1990, 1 syntype. [3.8 mm]. BRANN: plt. 42, fig. 519.

As with *Liotia c-b-adamsii*, I am disregarding the requirement in Article 32 (c) of the International Code of Zoological Nomenclature and retaining the hyphens, for otherwise the specific name is unpronounceable.

256. *Chemnitzia undata*, p. 431  
= *Turbonilla (Strioturbonilla) undata* (CARPENTER, 1857)

(Text figure 167)

Tablet 2002, 1 syntype. [1.6 mm]. BRANN: plt. 45, fig. 531.

The aperture in this specimen is broken, and the shell seems too young and worn to be identifiable; the sculp-

ture can be seen, only faintly, by looking through the shell, which is semi-transparent.

257. *Chemnitzia prolongata*, p. 429

= *Turbonilla* (*Turbonilla*) *prolongata* (CARPENTER, 1857)

(Text figure 168)

Tablet 1995, 1 syntype. [5.5 mm]. BRANN: plt. 45, fig. 524.

Spiral sculpture is faint, especially on the early whorls.

258. *Chemnitzia gibbosa*, p. 430

?

Tablet 1996, 2 syntypes, both fragmentary. [6.7 mm]. BRANN: plt. 46, fig. 525.

The larger specimen seems to me to be a rissoinid too worn for determination. The smaller is a columbellid, perhaps an *Aesopus*. The apex is wanting, and there is no sign of a columellar fold. DALL & BARTSCH (1909, p. 61; plt. 6, fig. 2) allocated the form to *Turbonilla* (*Pyrgolampros*) but indicated that such an identification was problematical.

#### ELLOBIIDAE

259. *Melampus olivaceus*, p. 178

= *Melampus olivaceus* CARPENTER, 1857

(Plate 58, Figure 67; Text figure 169)

Tablets 812 - 814, 17 syntypes (7 from tablet 812 photographed and 1 from tablet 814 drawn). [16 mm].

Authors have had no problem identifying this species.

#### SIPHONARIIDAE

260. *Siphonaria aequilirata*, p. 184

= *Siphonaria maura maura* SOWERBY, 1835

(Plate 58, Figure 68)

Tablet 866, holotype. [21.5 mm].

Carpenter seems not to have been aware of the amount of variability in this species.

261. *Siphonaria lecanium palmata*, p. 183

= *Siphonaria maura palmata* CARPENTER, 1857

(Plate 58, Figure 69)

Tablets 836 - 845, 56 syntypes (tablet 840 photographed). [25 mm].

Authors have identified the form correctly.

262. *Nacella peltoides* CARPENTER, 1864 b, p. 474

= *Williamia peltoides* (CARPENTER, 1864)

(Text figure 170)

Tablet 944, hypotype. [-]. BRANN: plt. 21, fig. 262.

This was cited on page 202 of the Mazatlan Catalogue as "*Nacella*, sp. ind." Later the species was described on the basis of better material from Cape San Lucas, Baja California. PALMER (1958, p. 259; plt. 25, figs. 15 - 16; and 1963, p. 367) has discussed and figured type material.

#### AMPHINEURA

The following notes are a summary of material as it is now available. I have turned to chiton specialists for advice on placement in modern terms, notably to Mr. Allyn G. Smith and Mr. Spencer Thorpe. Mr. Thorpe, after studying my photographs and notes, decided to contribute a separate commentary, to be submitted for publication at a future date.

263. *Lophyrus striatosquamosus*, p. 192

(Plate 59, Figure 91)

Tablet 897, holotype. [4.4 mm]. BRANN: plt. 18, fig. 250.

The surface is finely punctate to scaly; the girdle is not preserved.

264. *Tonicia forbesii*, p. 193

= *Tonicia forbesii* CARPENTER, 1857

(Plate 59, Figure 104)

Tablet 898, 1 syntype (here chosen as lectotype). [20 mm].

Authors seem to have recognized this form correctly; it was figured by PILSBRY (1893, Manual of Conch., vol. 14, p. 196; plt. 45, figs. 69 - 72) under the preoccupied name of "*T. crenulata* (SOWERBY, 1832)."

265. *Acanthochites arragonites*, p. 198

= *Acanthochitona arragonites* (CARPENTER, 1857)

(Plate 59, Figure 92)

Tablet 907, 1 syntype, 4 odd valves. [4.1 mm]. BRANN: plt. 21, fig. 258.

The articulated specimen (here chosen as lectotype) shows the bristle tufts well, but the drying girdle has arched it so much that it does not photograph well. There is a color pattern of pink and brown spots on white, and the margins of the girdle look scalloped. PALMER (1963, plt. 68, fig. 1) has figured a specimen from Cape San Lucas labelled by Carpenter.

266. *Lepidopleurus macandrei*, p. 195

= *Ischnochiton macandreae* (CARPENTER, 1857)

(Plate 59, Figure 93)

Tablet 904, holotype. [3.3 mm]. BRANN: plt. 20, fig. 255.

The spelling of the specific name was emended to

*macandreae* by Carpenter on page 550. The specimen was donated by Mr. Thomas Nuttall, and the collecting locality is not positively Mazatlan. Carpenter assumed it to be specifically identical to one from Mazatlan that was smashed during examination. His drawing shows 10 slits in the head valve, but I thought I could count 12. The girdle is wide and laps over the valves, almost concealing one of them.

267. *Lepidopleurus beanii*, p. 197

= *Chaetopleura beanii* (CARPENTER, 1857)  
(Plate 59, Figure 94)

Tablet 905, 1 syntype (here chosen as lectotype), 2 valves. [5.9 mm]. BRANN: plt. 20, fig. 256.

There are a few girdle setae on the entire specimen, rather long and curved. The mucro is sunken. Possibly the 2 odd valves are not specifically identical to the entire specimen; both are smoother and differently sculptured.

268. *Lepidopleurus bullatus*, p. 195

= *Chaetopleura bullata* (CARPENTER, 1857)  
(Plate 59, Figure 95)

Tablet 902, 1 syntype, 2 odd valves. [4.4 mm]. BRANN: plt. 20, fig. 254.

An articulated specimen, here chosen as lectotype, has parts of 2 valves broken out, and the 2 odd valves mounted separately may not be the same form. Girdle scales are minute.

269. *Lepidopleurus bullatus calciferus*, p. 195

= *Chaetopleura calcifera* (CARPENTER, 1857)  
(Plate 59, Figure 96)

Tablet 903, holotype. BRANN: plt. 20, fig. 254-b.

The type, somewhat contracted, is about 3 mm long. The girdle is not well preserved. The form is doubtfully distinct.

270. *Chiton flavescens*, p. 198

?= *Chaetopleura flavescens* (CARPENTER, 1857)  
(Plate 59, Figure 103)

Tablet 906, 3 syntypes, 2 odd valves. [4.1 mm]. BRANN: plt. 21, fig. 257.

The largest specimen shows 9 to 10 slits on the head valve; a smaller is attached within a dead *Crepidula*, and there is one subadult, badly contracted by the drying girdle.

271. *Lepidopleurus clathratus*, p. 195

?= *Lepidozona subclathrata* (PILSBRY, 1892)  
(Plate 59, Figure 97)

Tablet 901, holotype. [4.4 mm]. BRANN: plt. 20, fig. 253.

As Carpenter's drawing shows, the girdle is wide, with

fine scales; ribs are beaded. If this is a *Lepidozona*, as seems probable, the name must fall as a secondary homonym of *L. clathrata* (REEVE, 1847); Pilsbry has provided a replacement name.

## ADDENDUM

Carpenter described a number of other Panamic province mollusks in addition to those in the Reigen collection. Most have been discussed already by PALMER (1958, 1963), but as some of the types that were thought to be lost now have come to light, I can add a few more observations on these as well as on some Californian material.

272. *Diplodonta subquadrata* CARPENTER, 1856

= *Diplodonta subquadrata* CARPENTER, 1856  
(Plate 56, Figure 26)

Proc. Zool. Soc. London for 1855, p. 230.

This was described from Mazatlan but was not in the Reigen material. Authors seem to have identified the species correctly in spite of lack of illustration. PALMER (1958, p. 85) has discussed the form briefly. There are two syntypes in the British Museum collection, registry number 196384.

The generic name *Diplodonta* BRONN, 1831 has been rejected by many authors because *Taras* RISSO, 1826 has priority, but according to CHAVAN, the type species of the latter is indeterminate.

273. *Venus cortezi* CARPENTER, 1864

= *Chione (Chionista) cortezi* (CARPENTER, 1864)  
(Plate 55, Figure 19)

Report British Assoc. Adv. Sci. for 1863, p. 570. Type locality, Guaymas, Mexico.

Carpenter's proposal of the name comes uncomfortably close to being a *nomen nudum* or a name proposed in synonymy, but as it had been adopted prior to 1961 and seems to be useful (KEEN, 1958, p. 142; fig. 322), I would argue for its acceptance.

274. *Thracia squamosa* CARPENTER, 1856

= *Thracia squamosa* CARPENTER, 1856  
(Plate 56, Figure 32)

Proc. Zool. Soc. London for 1855, p. 229.

PALMER (1963, p. 320) has reprinted the original description. Carpenter's holotype, from the Cuming collection, type locality Mazatlan, was figured by Reeve in 1859 (Conch. Icon., vol. 14, plt. 3, fig. 16). I reproduced

this figure (KEEN, 1958, fig. 590). Two valves are in the Type Collection of the British Museum, registry no. 1966570; the right valve is somewhat broken.

275. *Litiopa divisa* CARPENTER, 1856

?=*Litiopa melanostoma* RANG, 1829  
(Plate 58, Figure 58; Text figure 171)

Proc. Zool. Soc. London for 1855, p. 234. "Cape San Francisco." [3.3 mm].

PALMER (1963, p. 339) has reprinted the original description. She points out that Carpenter had misgivings on the locality, which is apparently eastern Pacific but could have been in California or in Ecuador. The form is doubtfully distinct from *Litiopa melanostoma*, known in both the Atlantic and Pacific as a pelagic gastropod. There are now only 3 of the original 6 specimens on the mount. The apical 2 whorls are white, the next with fine axial riblets, the body whorl with faint spiral threads, and there is some variation in color and outline. The best specimen is here illustrated.

276. *Galerus* ?*sinensis*, var. *fuscus* CARPENTER, 1856  
=*Calyptrea* sp.  
(Plate 57, Figure 53)

Proc. Zool. Soc. London for 1855, p. 233.

Carpenter's original description is brief: "*G. sinensis*, t. *rufo-fusca*, huc et illuc lineis declivis instructa." He compares this to the British *Calyptrea sinensis* but because of the slightly darker color suggests the subspecific name *fuscus*. The holotype, which was in the Cuming collection marked "Gulf of California," might not have come from there. The registry number in the British Museum Type Collection is 1966636. If the shell actually came from West Mexican waters, one would have to consider the name a synonym of *Calyptrea mamillaris* BRODERIP, 1834, for there seem no clearcut points of distinction other than the brown coloration that suggests it is indeed *C. sinensis*.

277. *Erato* ?*maugeriae panamensis* CARPENTER, 1856  
=*Erato* (*Hespererato*) *panamensis* CARPENTER, 1856  
(Plate 58, Figures 66 a-b)

Proc. Zool. Soc. London for 1856, p. 162.

PALMER (1963, p. 345) has reprinted the original description. Three specimens that seem to me unquestionably to be the syntypes are in the British Museum collection. They do not carry a Carpenter label, but they are from Panama and have on the back of the mount, in the handwriting of E. A. Smith, the page reference to the Carpenter description. The specimen figured here

was illustrated by SOWERBY, 1859 (Thesaurus Conchyl., vol. 3, plt. 219, fig. 3) as "*Erato sulcifera*, var." The form has also been labelled *E. laevis*, var., and *E. maugeriae*. It seems to be distinct from *E. maugeriae* SOWERBY, 1832, of the West Indies, in having a lower spire and more inflated body whorl. Although it has not again been recorded in the West Coast literature, the species may be valid. It is close to *E. columbella* MENKE, 1847 but more uniformly colored, the outer lip not white. As I have pointed out recently (KEEN, 1966, Occ. Papers, Calif. Acad. Sci., no. 59, p. 23), this is probably a senior synonym of *E. marginata* MÖRCH, 1860, which, too, was compared to *E. maugeriae*.

278. *Sistrum* (?*ochrostoma*, var.) *rufonotatum* CARPENTER, 1864  
=*Morula rufonotata* (CARPENTER, 1864)  
(Plate 59, Figures 81 a-c)

Ann. Mag. Nat. Hist., ser. 3, vol. 14, p. 48. Type locality, Cape San Lucas, Baja California.

PALMER (1963, p. 347) has reprinted the original description. Her search for the holotype at the U. S. National Museum was unsuccessful. There are, in the British Museum's collection, 3 specimens on a glass mount labelled in Carpenter's handwriting, part of some material that had been sent by the Smithsonian Institution during the 1860's on an exchange arrangement. These are therefore syntypes; their registry number is 1967576. The species seems to be distinct, characterized by a row of reddish dots below the peripheral cords. Dr. Donald Shasky has collected similar specimens on the Tres Marias Islands and the adjacent mainland of West Mexico.

279. *Pisania elata* CARPENTER, 1864  
=*Fusinus* (*Aptyxis*) *cinereus* (REEVE, 1847)  
(Plate 58, Figures 65 a-b)

Ann. Mag. Nat. Hist., ser. 3, vol. 14, p. 49.

The type specimen should be at the U. S. National Museum but has not been detected. PALMER (1963, p. 354) reprinted Carpenter's description and figured a badly encrusted specimen from his collection at McGill University. In the British Museum there is one small specimen from Cape San Lucas, received from the Smithsonian Institution, that may well be a syntype. There are 4 lots labelled "*Pisania elata* CARPENTER," all from the Cuming collection, either without locality or merely as from "California." All these specimens are good *Fusinus cinereus*; 2 are figured here. Perhaps the missing type may still be at the U. S. National Museum under a changed label.

280: *Olivella glandinaria* CARPENTER, 1857, ex Nuttall MS

= *Olivella biplicata* (SOWERBY, 1825)  
(Plate 59, Figures 89 a-b)

Proc. Zool. Soc. London for 1856, p. 227. Type locality, California.

There are 2 specimens in the Nuttall collection at the British Museum with a Carpenter label. Although he was apparently aware that the form was not distinct, he made a gesture of tribute for Nuttall's work by salvaging in part a name that Nuttall had chosen, *Glandinaria californica*. The types are well within the range of variation of Sowerby's species; registry number, 1861.5.20.54.

281. *Drillia punctatostriata* CARPENTER, 1856  
= *Crassispira punctatostriata* (CARPENTER, 1856)  
(Plate 58, Figure 75)

Proc. Zool. Soc. London for 1856, p. 164. Type locality, Panama.

PALMER (1963, p. 361; plt. 68, figs. 5, 6) has reprinted the original description and has given a figure of the holotype in the British Museum. I am adding a figure that is larger and shows more details of sculpture. There

is a typographical error in PALMER's plate explanation that makes the shell seem minute - "x 7" should read, "x 2."

This species unfortunately was omitted from my book (KEEN, 1958), for the species was at that time unfigured and its status seemed uncertain. Now it proves to be so similar in form to *Crassispira solitaria* PILSBRY & LOWE, 1932, from Mazatlan, that I see no means of separation. It may be, therefore, that the range of *C. punctatostriata* should be considered as the southern part of the Gulf of California to Panama.

282. *Melampus bridgesii* CARPENTER, 1856  
= *Tralia bridgesii* (CARPENTER, 1856)

Proc. Zool. Soc. London, pt. 24, p. 161. Type locality, Panama.

PALMER (1963, p. 366; plt. 67, figs. 14, 15) has reprinted the original description and figured a specimen from the British Museum collection as "holotype," registry no. 196312. As Carpenter states there were 3 specimens in the lot, this must be a syntype, which is here selected as lectotype. Under modern allocation the form is not a *Melampus* but a *Tralia*.

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Numbers refer to paragraphs, not to pagination or to CARPENTER catalogue.

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## Effect of Feeding by *Armina californica* on the Bioluminescence of *Renilla koellikeri*

BY

HANS BERTSCH

Franciscan Theological Seminary, Old Mission, Santa Barbara, California 93105

THE BIOLUMINESCENCE of the sea pansy (*Renilla koellikeri* PFEFFER, 1886) has been extensively studied in the past two decades (HARVEY, 1952; JOHNSON, 1955; CORMIER, 1961; etc.). Most of the published information treats of chemical analyses of the bioluminescent substance produced by *Renilla* when stimulated. Observations on the behavior of the living animal were performed to supplement the chemical information, and indicated that *Renilla* exhibits a general pattern of yellow-green bioluminescence that is confined to the rachis, but is able to be elicited by stimulating any part of the animal. The pattern varies between a local glow, a wave passing across the entire rachis, or a general throb, depending on the intensity of the stimulation. Under the control of the nerve net, the reaction shows an apparent pattern of facilitation, with increased stimulation causing increased bioluminescence. Waves simultaneously elicited from two different parts of the *Renilla* will dissipate when the nerve impulses meet, rather than continuing across the entire rachis.

The slime that bioluminesces is apparently produced by the animal even when the response is inhibited by an external light source. Such a light source will inhibit that part of the rachis that is exposed to it without affecting the other side of the rachis, indicating a factor other than nerve net conduction in the production of the bioluminous response. Recovery of inhibited bioluminescence follows the Bunsen-Roscoe Law.

Observers have mentioned (LANCE, 1961; RICKETTS & CALVIN, 1962) that *Armina californica* (COOPER, 1862) will feed on *Renilla*, but I was unable to find in the literature any details about the feeding patterns. Therefore I conducted a group of experiments to determine whether the feeding of *Armina* on the *Renilla* would effect any special behavioral responses on the part of the prey.

First, general observations were made of their inter-specific behavior; second, a special experiment was performed to determine whether the feeding of *Armina* would cause a bioluminescent reaction on the part of the

*Renilla*; and, finally, a simple experiment was devised to determine whether the body juices of the *Armina* would produce an inhibitory or an enhancing effect on the wave of bioluminescence.

### METHOD

For the first experiment, the method was just general observation of *Armina* feeding on *Renilla*. The animals were in a tank through which fresh sea water was constantly running.

The second experiment was to test the hypothesis that the *Renilla* would give a bioluminous response when the *Armina* feeds on it. One animal of each kind was placed in a bowl with the other. The bowl contained sea water and a sandy bottom to better simulate their natural environment. Observations were made in the dark, with sufficient light only to see the position and behavior of the two animals, but not enough to inhibit the bioluminescence of the *Renilla*. Control experiments were also performed, with a *Renilla* alone in a bowl with sand and sea water, or with *Renilla* and a non-feeding *Armina* together.

The third experiment, to test the hypothesis that fluid from the *Armina* would inhibit the bioluminescence of the *Renilla*, involved macerating one *Armina* in a blender with 15 ml of sea water to aid the grinding process. This suspension was placed on the rachis of a *Renilla* with an eye dropper. Visual observation in a darkened environment would then determine if there were any differences between the part with the *Armina* suspension on it, and the part without. A stimulating probe induced the wave response and differences would be judged according to deviations from the normal bioluminescent pattern.

### RESULTS

The general behavior of the *Renilla* when *Armina* feeds upon it involves a retraction of the anthocodia and mus-

cular contractions of the rachis. The bioluminescent response was tested for only in the second experiment and will be discussed there.

Under the laboratory conditions (both with a sand bottom and with only a glass bottom to the sea water tank), the *Armina* ate the anthocodia, the rachis, and the tip of the peduncle when exposed. Further experiments should be performed to determine preference habits of the *Armina* for these various parts of the *Renilla*, and how the *Armina* senses the presence of the *Renilla*.

The results of the second experiment were that every time the wave response was elicited from the *Renilla*, the *Armina* was feeding on it. There were times during the 15 trials when the *Armina* was ingesting the *Renilla*, but without stimulating the wave response. Often the flashes would occur in rapid sequences of 6, 8, 10 or more waves. The *Armina* exhibited no avoidance behavior, as far as could be told from unaided visual observation. The *Armina* was also observed moving across the rachis, but without feeding. At these times there were no wave patterns elicited from the *Renilla*, although the rachis of the animal was curling and folding extensively.

The results of the third experiment failed to substantiate the hypothesis. No visual differences were observed between that part of the rachis covered with the macerated *Armina* and that part which was not covered by the preparation. This result did not vary, no matter how thoroughly the rachis was covered by the suspension.

## DISCUSSION

There is a stimulation threshold below which the *Renilla* will not exhibit a bioluminescent response. Certain behavioral patterns of an *Armina* fall beneath this level (crawling across the rachis, righting itself after having fallen onto the *Renilla*, burrowing under the animal). The only observed behavior of the *Armina* that caused the *Renilla* to bioluminesce was feeding on any part of the animal.

Continued identical stimulation can possibly result in a raising of the threshold level necessary to produce the wave response. This would explain why a number of times the *Armina* was observed to be apparently eating, but without eliciting the wave response. Any theory that the bioluminescent reaction serves as a defense mechanism would have to account for this lack of behavioral response.

From the third experiment one must conclude (tentatively) that the *Armina* possesses no chemical substance that will inhibit the bioluminescence. The hypothesis had been that such a chemical may exist as a narcotizing agent. More refined measurements of the biochemistry of *Armina* could result in either a verification or a nulli-

fication of the conclusion drawn from this segment of the experiment.

## SUMMARY

When *Armina* feeds on *Renilla*, it will elicit a bioluminescent response which other behavior patterns will not evoke. The body fluid of *Armina* seems to have no effect on the bioluminescence. Other reactions of the *Renilla* include muscular contractions of the rachis and retraction of the anthocodia. *Armina* will feed on any part of the *Renilla*.

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# A New Marine Mollusk from Mozambique in the Genus *Festilyria* PILSBRY & OLSSON, 1954

(GASTROPODA : VOLUTIDAE)

BY

CLIFTON STOKES WEAVER

Hawaiian Malacological Society

2777 Kalakaua Avenue, Honolulu, Hawaii 96815

(Plate 60; 1 Map)

IN 1966 I OBTAINED for Mr. John duPont, a shell which had been dredged in 40 fathoms of water off Boa Paz, Mozambique, Portuguese East Africa. The specimen was empty but in excellent condition (see Plate 60, Figures 1 and 2). Subsequently, I learned of the existence of a second conspecific shell dredged alive in about 12 fathoms of water 150 miles northeast of Lourenço Marques, a town only a few miles south of Boa Paz (see Map). This specimen, with animal preserved, is in the collection of the Department of Mollusks, Museum of Comparative Zoology, Harvard University, Cambridge, Massachusetts. These 2 specimens seem to belong to a hitherto unknown species.

The new species appears to be related to both *Festilyria ponsonbyi* (E. A. SMITH, 1901) (see Plate 60, Figures 3 and 4) and *F. festiva* (LAMARCK, 1811) (Plate 60, Figures 5 and 6). It is unfortunate that the animals of these 2 species are unavailable for study. However, there are sufficiently strong morphological differences between the 3 taxa to warrant specific separation.

In my arrangement of subfamilial and generic classification I follow PILSBRY & OLSSON, 1954.

Fulgorarinae PILSBRY & OLSSON, 1954

1954. *Fulgorarinae* PILSBRY & OLSSON, Bull. Amer. Paleont. 35 (152): 16

*Festilyria* PILSBRY & OLSSON, 1954

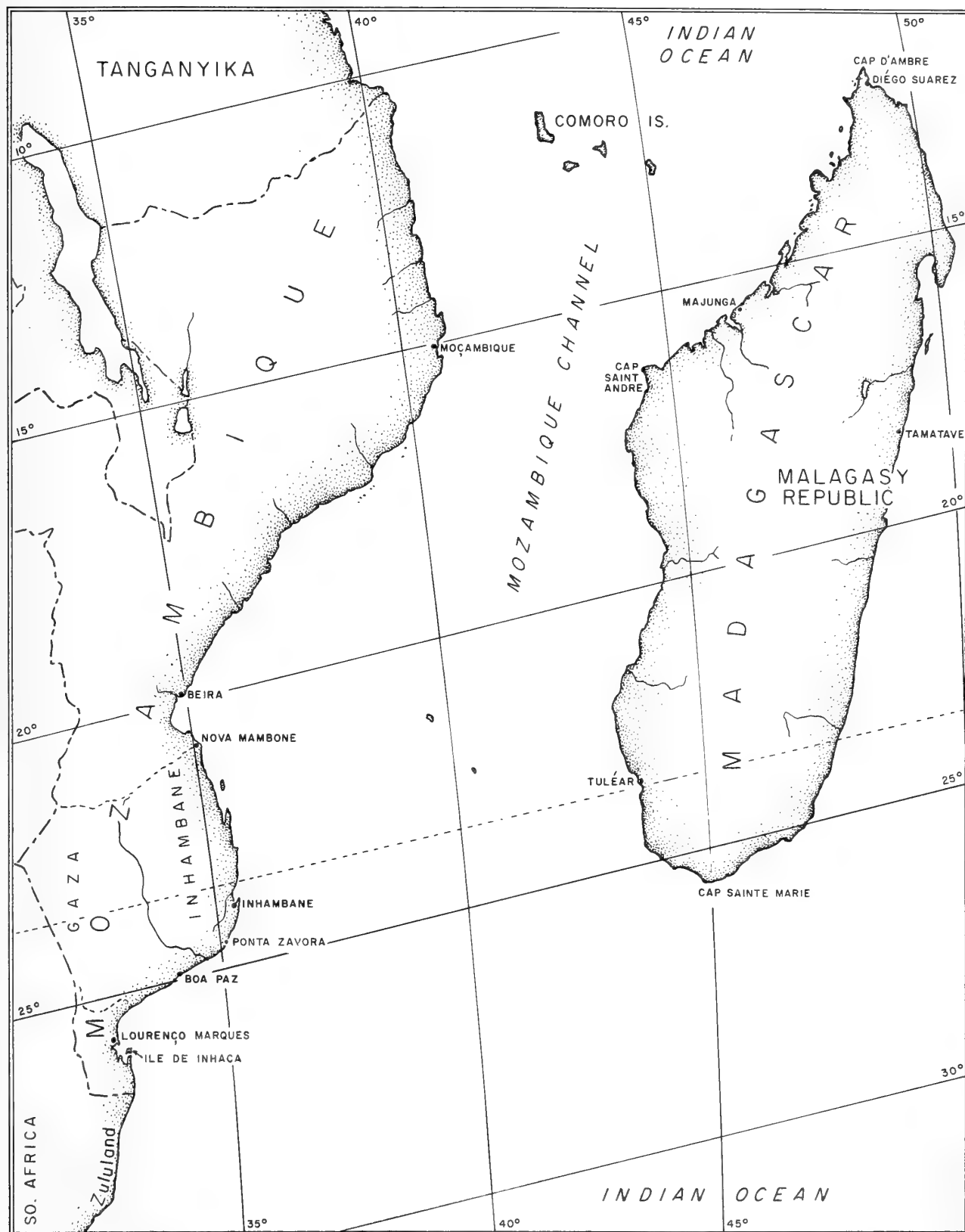
1954. *Festilyria* PILSBRY & OLSSON, Bull. Amer. Paleont. 35 (152): 24

**Type Species:** *Voluta festiva* LAMARCK, 1811, by OD. Recent, Africa.

**Distribution:** In addition to the new taxon being described below, there are 3 other Recent species in the genus, all of which inhabit moderately deep water off East Africa. They are *Festilyria africana* (REEVE, 1856), *F. festiva* (LAMARCK, 1811), and *F. ponsonbyi* (E. A. SMITH, 1901). Two species, *F. africana* and *F. ponsonbyi*, are known almost exclusively from specimens removed from the stomachs of fishes.

**Diagnosis:** Shells medium to large, solid, ovate or fusiform. Spire high or low, turreted, or with rounded shoulders; apex blunt. Protoconch pupiform, medium to large, smooth. Teleoconch sculpture consists of shoulder nodules or sharp tubercles which may or may not continue from suture to suture as low, rounded axial ribs. Aperture semi-ovate. Outer lip simple, slightly thickened, bevelled. Columella with 3 rather strong anterior plaits (the second being strongest), followed by several weak plaits covering  $\frac{1}{2}$  to  $\frac{2}{3}$  parietal area. A black callus or blotch may or may not be present at upper and lower end of columella. Siphonal notch narrow, deep; fasciole weak, without defining ridge. Periostracum absent; horny operculum present (Plate 60, Figure 7).

**Remarks:** PILSBRY & OLSSON (1954) stated that a fasciole was absent in the type species, *Festilyria festiva*. This must have been a *lapsus* on their part as I have examined a large adult specimen of *F. festiva* at the American Museum of Natural History, New York City, and observed a distinct fasciole. Mr. John duPont confirmed this observation when he examined several specimens of *F. festiva* at the British Museum (Natural History), London. Apparently the lack of a defining fasciole ridge caused this error. Furthermore, some books have



drawings of *F. festiva* that show a distinct fasciole (KIE-  
NER, 1839, plt. 22, fig. 2, dorsal view) and some show  
none at all (REEVE, 1849, plt. 12, fig. 28 b). This, no  
doubt, has also contributed to the error.

*Festilyria duponti* WEAVER, spec. nov.

(Plate 60, Figures 1 and 2)

**Type Specimens:** Holotype, Delaware Museum of Nat-  
ural History No. 13706; Paratype, Museum of Com-  
parative Zoology, No. 262150.

**Type Locality:** In 40 fathoms of water off Boa Paz,  
Mozambique, Portuguese East Africa.

**Range:** From waters off Boa Paz to a point 150 miles  
northeast of Lourenço Marques (24° 64' S; 34° 50'  
E).

**Habitat:** The only known living specimen (Paratype)  
was dredged in 12 fathoms; substrate unknown.

**Dimensions:** Holotype length 124.4 mm, maximum dia-  
meter 56.5 mm, aperture length 72.6 mm, maximum dia-  
meter of 2<sup>nd</sup> protoconch whorl 3.5 mm.

**Description:** Shell moderately large for genus, solid,  
elongate-fusiform. Spire high, turreted, with rounded  
apex. Protoconch pupiform, rather large, of 2½ smooth,  
deeply sutured, flesh-colored whorls. Teleoconch of about  
5½ strongly turreted and sculptured whorls. Sculpture on  
early whorls consists of axial ribs, 15 such ribs on pen-  
ultimate whorl of holotype, diminishing to blunt shoulder  
nodules on later whorls. On early teleoconch whorls  
axial ribs are crossed by many closely spaced revolving  
lirae which disappear on later whorls. At anterior tip  
of adult body whorl are 8 or more strong revolving lirae  
bordering the fasciole. Aperture wide, semi-ovate, about  
⅔ total length of shell. Outer lip simple, slightly thickened,  
bevelled. Columella arched, with 3 rather strong anterior  
plaits (the second being strongest), followed posteriorly

by 4 weaker plaits to midpoint on columella. Siphonal  
notch narrow, deep; fasciole weak. A black callus at pos-  
terior junction of outer lip with parietal wall and a black  
blotch at anterior end of columella. Base color flesh, pro-  
fusely overlaid with revolving zones of pinkish-brown  
blotches; the narrow, pale, intermediate areas crossed by  
numerous, short, curved, irregular pinkish-brown lines.  
Inner edge of outer lip spotted with black where revolving  
pinkish-brown lines terminate. A large horny operculum  
is present.

**Animal and Radula:** Top of broadly expanded foot  
creamy-white with numerous closely spaced reddish-brown  
lines radiating outwards. These lines often split and ana-  
stomose. Siphon and tentacles encircled by narrow bands  
of reddish-brown.

I have not had the opportunity to study the anatomy  
of the soft parts of the paratype at Harvard.

**Remarks:** Before comparing *Festilyria duponti* with its  
closest relative, *F. festiva*, the following remarks should  
be noted: The holotype of *F. festiva* illustrated in this  
paper is a juvenile shell and I have no photograph of  
an adult specimen. Therefore, I have referred to REEVE  
(1849, plt. 12, fig. 28 a) in making comparisons with a  
fully adult shell, as well as referring to my notes on the  
adult shell I studied at the American Museum of Natural  
History in New York.

*Festilyria duponti* differs from *F. festiva* as follows:  
Shell is smaller, lighter in weight, and more attenuated in  
outline; strongly shouldered and turreted whorls are in  
sharp contrast to gently sloping non-turreted whorls of  
*F. festiva*; ribs do not run from suture to suture (other  
than on first 2 teleoconch whorls); protoconch is smaller  
and has 1 less whorl.

Compared to *Festilyria ponsonbyi*, *F. duponti* exhibits  
the following differences: It has ribs which terminate  
posteriorly as low nodules rather than the ribless pointed  
tubercles of *F. ponsonbyi*; protoconch is twice as large;  
shell is larger and more attenuated; no black callus or  
blotch appears on the parietal area of *F. ponsonbyi*.

### Explanation of Plate 60

Figures 1 and 2: *Festilyria duponti* WEAVER, spec. nov. Holotype,  
ex DMNH no. 13706; dredged dead in 40 fathoms off Boa Paz,  
Mozambique. Height 124.4 mm; maximum diameter 56.5 mm;  
photographs by Clifton Weaver.

Figures 3 and 4: *Festilyria ponsonbyi* (E. A. SMITH, 1901), ex  
duPont collection, from the stomach of a fish caught off Durban,  
Natal, Republic of South Africa. Height 100.8 mm; maximum dia-  
meter 51.2 mm; photographs by Clifton Weaver.

Figures 5 and 6: *Festilyria festiva* (LAMARCK, 1811). Holotype, ex  
MNHN, general collection of Volutidae No. 57; "Africa;" a juve-

nile specimen; height 71 mm, maximum diameter 31.5 mm; photo-  
graphs courtesy Mr. H. Chevallier, MNHN.

Figure 7: Operculum from paratype of *Festilyria duponti* WEAVER,  
spec. nov., ex MCZ no. 262150; animal dredged alive in 12 fathoms,  
150 miles northeast of Lourenço Marques, Mozambique; photo-  
graph courtesy Dr. Ruth Turner, MCZ.

Explanation of abbreviations used: DMNH=Delaware Museum  
of Natural History, Greenville, Delaware. MCZ=Museum of  
Comparative Zoology, Harvard University, Cambridge, Massachu-  
setts. MNHN=Muséum National d'Histoire Naturelle, Paris,  
France.

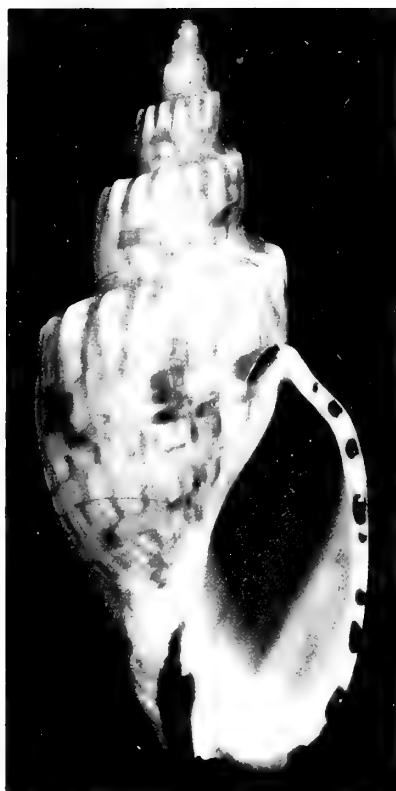


Figure 1



Figure 5



Figure 2



Figure 6



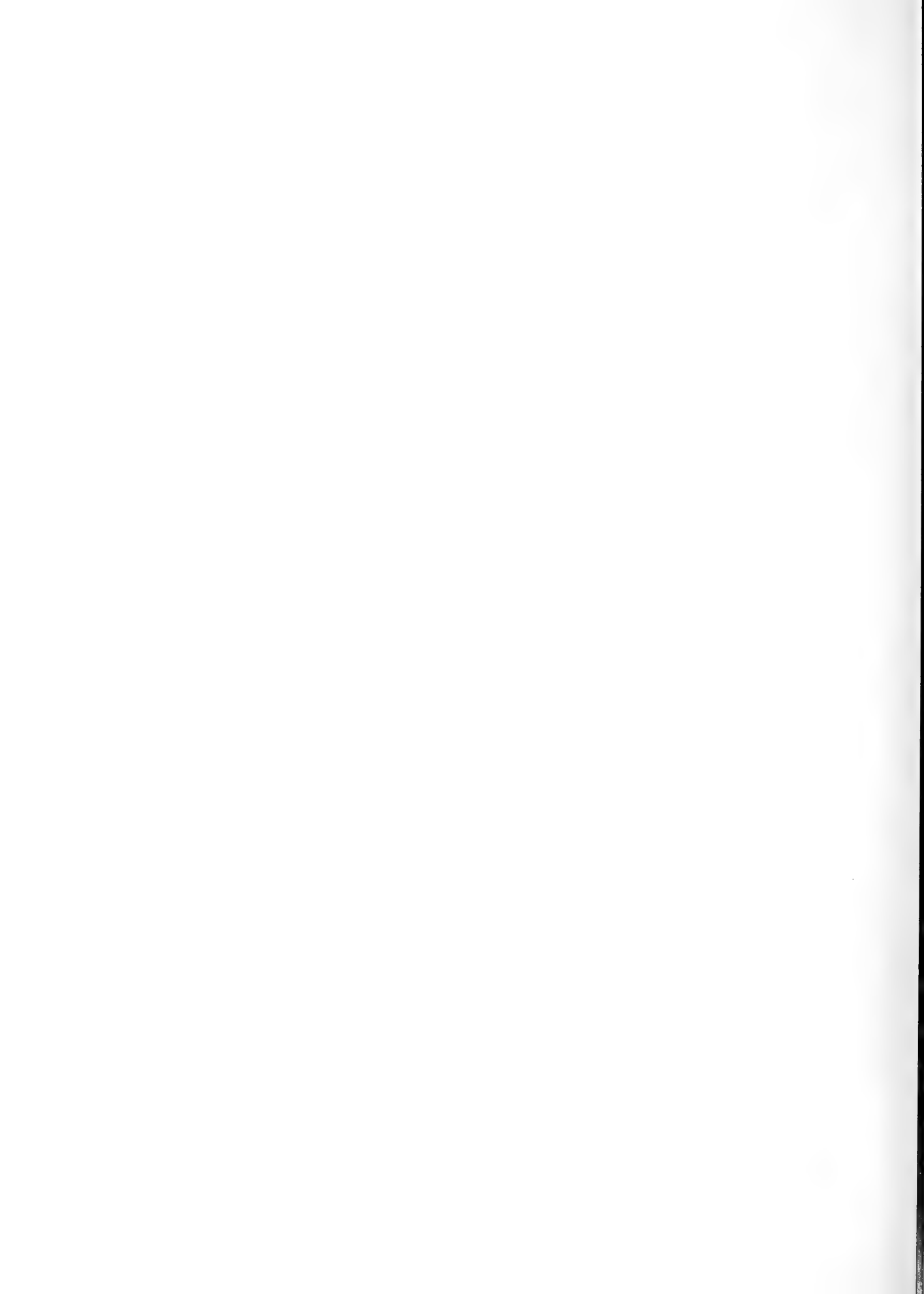
Figure 3



Figure 7



Figure 4



It gives me pleasure to name this beautiful species in honor of my friend and associate, Mr. John E. duPont, whose interest in the family Volutidae is well known.

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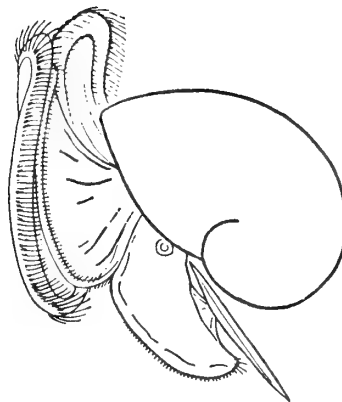
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## METHODS & TECHNIQUES

### Boiled Lettuce and Cress as Diet Supplements for Certain Species of Mollusks

BY

T. W. FISHER

Department of Biological Control  
University of California, Riverside, California 92502

AN ISOLATED BIT of information such as this normally would be included in a more extensive biological study; however, the boiled leaf technique has produced such excellent results during the past several months it seems worthy of bringing to the attention of Veliger readers. No reference to this specific technique has been found in a hurried search of the literature (KINGSTON, 1966; KRULL, 1937a, b). Nonetheless, it is doubtful that other workers have not chanced on this disarmingly simple, yet highly successful, means of feeding certain species of terrestrial and fresh water mollusks.

#### METHOD OF PREPARATION

Coarse outside leaves of romaine and head lettuce and mature large-leafed water cress, *Nasturtium officinale* R.BR., have been utilized. The unaltered plant material as whole leaves — no shredding is necessary — is immersed about 10 seconds in boiling water and then placed in cold tap water for immediate use or storage. With weekly water changes a supply of boiled cress can be kept (in water) at 40°F for several weeks. Boiled lettuce does not hold up as well and is best used within one week. Depending on the number of snails to be fed, entire or fragmented lettuce leaves can be placed with the snails in amounts dictated by experiment to be consumed in 48 hours. Boiled cress sinks and boiled lettuce floats. Consequently, the latter is brought within reach of benthic snails if it is weighted down with small rocks.

#### REARING CONTAINERS

In the laboratory aquatic snails are reared in 48 ounce covered plastic containers (BAY, 1967) and 5-gallon aquaria which are equipped with sub-sand filters and air bubblers. Larger numbers are reared in a greenhouse in

wooden tanks measuring approximately 3 ft by 5 ft of surface by 6 inches deep with a very feeble flow-through of water, and with a layer of sand/gravel/soil on the bottom. *Succinea* is maintained in a large covered rigid plastic food container with a layer of soil which is covered with decaying grasses. In the laboratory *Helix* and *Limax* are maintained in 5-gallon aquaria with soil. A large colony of *Helix* is maintained in a lathhouse in a screen-covered pit with sides of concrete blocks.

#### MOLLUSKS REARED

Species which respond well to the boiled cress lettuce diet are the following:

HYDROBIIDAE: *Fontelicella californiensis* GREGG & TAYLOR seem to prefer boiled cress, but readily accept boiled lettuce. The following mollusks have been fed mainly boiled lettuce: LYMNÆIDAE: *Stagnicola proxima* (*palustris nuttalliana* (LEA)); PLANORBIDAE: *Helisoma tenue californiense* F. C. BAKER; PHYSIDAE: *Physa virgata* GOULD, *P. gyrina* SAY. Terrestrial species which readily consume this diet are: SUCCINEIDAE: *Succinea californiensis* FISCHER & CROSSE; LIMACIDAE: *Limax flavus* LINNAEUS; HELICIDAE: *Helix aspersa* MÜLLER. It is well known that *H. aspersa* feeds on raw lettuce leaves as well.

#### DISCUSSION

Apparently, boiling breaks down the plant tissues, thus permitting immediate feeding even by very early juvenile mollusks. In the aquaria and larger wooden culture tanks previously mentioned raw lettuce usually lies in the water for two days before newly hatched snails will touch it, and they do not swarm on it until the leaf is in a state of decay one or two days later. A cooked leaf, on the other hand, is attacked at once and may be skeletonized in 4 hours if snails are abundant. In 24 hours usually only the coarsest vascular tissue remains.

Investigation into a better snail feeding technique was prompted by the need for a constant supply of small juvenile snails which are used as hosts for first instar larvae of marsh flies (Diptera: Sciomyzidae). After a few hours in snail cultures bits of boiled lettuce or cress can be torn away with juvenile snails still attached and transferred *en masse* to the fly cultures.

An interesting side observation has been the suitability of this diet for various other fresh water invertebrates. These include, among others, Ostracoda, Amphipoda (*Gammarus* spp.), Eubranchiopoda, and planaria. These animals frequently attach themselves to the boiled plant material and it is assumed they are feeding on it.

The foregoing listing of mollusks includes all of the species, representing 7 families, that have been reared on

the boiled lettuce diet. It is hoped that this diet will find broader use and acceptance and that it will make possible the laboratory rearing of species whose biologies are now incompletely understood.

An extension of this technique might apply to the study of small cryptic terrestrial mollusks. Since it is often stated that many land mollusks are "humus feeders," the boiled leaf technique using leaves from their environment may serve as a short cut to "humus."

If close control of mollusk cultures is required, boiling of vegetation eliminates contaminants such as extraneous fungi, arthropods, mollusks, etc. This method should not be construed as a definitive, or complete, diet for mollusks, but rather as a very useful supplement to the epiphyton normally available, miscellaneous decaying or green plant material and shell building materials such as calcium carbonate, limestone or shell.

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### NOTES & NEWS

A. M. U.

### Pacific Division

The Executive Board of the American Malacological Union - Pacific Division will meet at Asilomar Conference Grounds, Pacific Grove, California on Thursday, June 20, 1968 at 1:30 p. m. The annual Business Meeting of the AMU-PD will follow immediately at 2:00 p. m. For reasons beyond the control of the elected officers it was impossible to organize any other program for the 1968 conference.

W. S. M.

The first Annual Meeting of the Western Society of Malacologists will be held at the conference grounds at Asilomar State Park, Pacific Grove, California June 19 to 22, 1968. Scientific papers, symposia on related problems, and exhibits will be presented in the various fields related to the study of malacology and invertebrate zoology.

All persons interested in malacology and conchology are cordially invited to attend, and participate in, this historic meeting. Excellent accommodations in varying price ranges (American plan) will be available for those making their reservations early.

For information on the conference or on membership in the Society, please address the Secretary, Mrs. Paul O. Hughes, 12871 Foster Road, Los Alamitos, CA 90720.

### Invalid Names in Oysters

BY

KENNETH JAY BOSS

Museum of Comparative Zoology, Harvard University,  
Cambridge, Massachusetts 02138

Recently 8 new names for species in the family Ostreidae (Mollusca; Bivalvia) were introduced into the literature by GILBERT RANSON (1967. Les espèces d'huitres vivant actuellement dans le monde, définies par leurs coquilles larvaires ou prodossoconques. Étude des collections de quelques-uns des grands musées d'histoire naturelle. *Rev. Trav. Inst. Pêches marit.*, 31 (2): 127-199, figs. 1-25; (3): 205-274, figs. 26-55).

Although these so-called new species are accompanied by "illustrations" - line drawings or photomicrographs of prodossoconchs at magnifications of 200 x and above, they are not validly introduced or available since they do not satisfy Article 13 (a) of the International Code of Zoological Nomenclature (1964)' which states:

... a name published after 1930 must be either

(i) accompanied by a statement that purports to give characters differentiating the taxon; or

(ii) accompanied by a definite bibliographic reference to such a statement; or

(iii) proposed expressly as a replacement for a pre-existing available name.

Ranson has not fulfilled any of these criteria. Neither a written description, nor a comparison with related species, nor an indication of type-locality, nor a citation of type material are given. The names, consequently, are not nomenclatorially available, and no zoologist should cite them. Since they are unavailable there is not even any need to place these names on the Official Index of Rejected and Invalid Specific Names in Zoology.

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## Important Notice!

Because of drastic changes in Postal Regulations, which went into effect on January 7, 1968, we will no longer be able to include in our January issue an envelope as a reminder that dues are payable. Other changes affect the cost of returning and remailing of undelivered copies of the journal. In addition, the mailing rate has been increased and will be increased annually on January 1 each year for the next several years — provided that there is not some extra-ordinary increase made at some other date. Changing the addresses also has recently been increased. After a very careful study of the whole problem, we find that a change of address alone costs us just one cent less than a dollar; return and remailing of copies because of the addressee having moved causes us an expenditure of a minimum of one dollar (depending on the weight of the particular issue and the distance of the original address). Since our charges reflect less than the actual cost of producing the magazine, we cannot any longer absorb the costs for these extraneous services. We are forced to ask that with each change of address our members and subscribers send along one dollar. For re-mailing a returned copy we are asking a reimbursement of \$2.-, a fee which will include the change of address. As we are not charging for the time consumed in rendering the service, and as we are not breaking even on the charges for returning and remailing, we earnestly request that we be informed at least four weeks before the change of address becomes effective. If that is impossible, then we urge that arrangements be made with the local postoffice for forwarding all second class mail — a service which, in view of all other charges, is very economical.

## CALIFORNIA

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At a Regular Membership Meeting of the CALIFORNIA MALACOOLOGICAL SOCIETY, Inc. the following policies were adopted by unanimous vote:

There will be an initiation fee of \$2.- (in addition to the annual dues) for persons joining the Society on or after January 1, 1967.

Members receive *The Veliger* free of further charges and are entitled to purchase one copy of any supplement published during the current membership year at a special discount (to be determined for each supplement).

Membership renewals are due on or before April 15 each year. If renewal payments are made after April 15 but before March 15 of the following year, there will be a re-instatement fee of \$1.-. Members whose dues payments (including the re-instatement fee) have not been received by the latter date, will be dropped from the rolls of the Society. They may rejoin by paying a new initiation fee. The volume(s) published during the time a member

was in arrears may be purchased, if still available, at the regular full volume price plus applicable handling charges.

## BOOKS, PERIODICALS, PAMPHLETS

### Marine Shells of the Pacific

by WALTER O. CERNOHORSKY. Pacific Publ. Pty. Ltd. Sydney, Australia. \$6.50 Austr., ≈ \$9.50 U. S. 248 pp; 60 halftone plates; 20 text figs.

This book, while primarily based on the molluscan fauna of Fiji, will be very useful to the collector of shells from a much wider area than that island group. The numerous excellent photographs will greatly assist in the identification of species belonging to the families Bursidae, Colubrariidae, Cypraeidae, Ovulidae, Triviidae, Muricidae, Mitridae, Olividae, Terebridae, and Conidae. It would appear that a second and, possibly third, volume in a series may be coming forth, which, if of the same high quality as the present volume, would certainly be welcomed by a large public.

In addition to the taxonomic treatment of the many species, several other chapters add to the value of the book. We especially like the one on the photography of shells as the detailed instructions will enable even a beginner in the new art to obtain satisfactory results. Other portions which no doubt will be appreciated widely are the ones dealing with collecting techniques, the removal of radulae for study, and a short glossary.

RS

### Les Protoconques ou Coquilles Larvaires des Cyprées

by GILBERT RANSON. *Mém. Mus. Nat. Hist. Nat.*, ser. A, 47 (2): 93 - 126; 39 halftone plates. Paris, 1967.

On the basis of outstandingly fine photographs of 149 specimens (cypraeid shells apparently ground down to expose the protoconch) and the examination by the author of an amazingly large number of specimens, Dr. Ranson comes to the conclusion that the majority of species belong to but a single genus, in which KAY in 1957 concurred. In the copy graciously sent to your editor there is a handwritten list of 6 species which could not be examined because the collection of the Paris Museum contains only a single specimen of each. Therefore Ranson does, by implication, not decide at this time that they

should be included in the genus *Cypraea*. The 6 species are: *Cypraea teulerei*, *C. pulicaria*, *C. euclia*, *C. saulae*, *C. gracilis* and *C. labrolineata*.

It would appear to this reviewer that the illustrations lend themselves, if taken by themselves and without consideration of other characters, such as shell, radula, soft parts, for a deviating interpretation, one which, in fact, would support a different approach. It seems to allow a logical grouping into what might be at least subgenera, although in many instances the differences seem to be of sufficient magnitude to justify generic separation.

If nothing else, this paper should stimulate a lively debate between the less conservative interpreters of the genus *Cypraea* (or, should we say 'Supergen'?) and the (possibly) ultra-conservative interpreters.

RS

#### The Proboscis and Oesophagus of some British Turrids

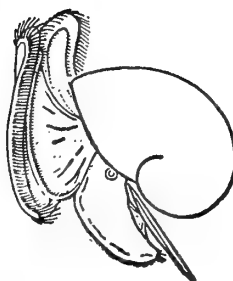
by EDMUND H. SMITH. Trans. Roy. Soc. Edinburgh 67 (1): 1 - 21; 17 text figs. 1967.

On the basis of the examination of a number of representatives of various genera of turrids, the author describes two new types of proboscides, calling one type A or intraembolic and the other type B or polyembolic.

RS

#### The Neogastropod Stomach, with Notes on the Digestive Diverticula and Intestine.

by EDMUND H. SMITH. Trans. Roy. Soc. Edinburgh 67 (2): 24 - 42; 11 text figs. 1967.



**THE VELIGER** is open to original papers pertaining to any problem concerned with mollusks.

This is meant to make facilities available for publication of original articles from a wide field of endeavor. Papers dealing with anatomical, cytological, distributional, ecological, histological, morphological, physiological, taxonomic, etc., aspects of marine, freshwater or terrestrial mollusks from any region, will be considered. Even topics only indirectly concerned with mollusks may be acceptable. In the unlikely event that space considerations make limitations necessary, papers dealing with mollusks from the Pacific region will be given priority. However, in this case the term "Pacific region" is to be most liberally interpreted.

It is the editorial policy to preserve the individualistic writing style of the author; therefore any editorial changes in a manuscript will be submitted to the author for his approval, before going to press.

Short articles containing descriptions of new species or lesser taxa will be given preferential treatment in the speed of publication provided that arrangements have been made by the author for depositing the holotype with a recognized public Museum. Museum numbers of the type specimens must be included in the manuscript. Type localities must be defined as accurately as possible, with geographical longitudes and latitudes added.

Short original papers, not exceeding 500 words, will be published in the column "NOTES & NEWS"; in this column will also appear notices of meetings of the American Malacological Union, as well as news items which are deemed of interest to our subscribers in general. Articles on "METHODS & TECHNIQUES" will be considered for publication in another column, provided that the information is complete and techniques and methods are capable of duplication by anyone carefully following the description given. Such articles should be mainly original and deal with collecting, preparing, maintaining, studying, photographing, etc., of mollusks or other invertebrates. A third column, entitled "INFORMATION DESK," will contain articles dealing with any problem pertaining to collecting, identifying, etc., in short, problems encountered by our readers. In contrast to other contributions, articles in this column do not necessarily contain new and original materials. Questions to the editor, which can be answered in this column, are invited. The column "BOOKS, PERIODICALS, PAMPHLETS" will attempt to bring reviews of new publications to the attention of our readers. Also, new timely articles may be listed by title only, if this is deemed expedient.

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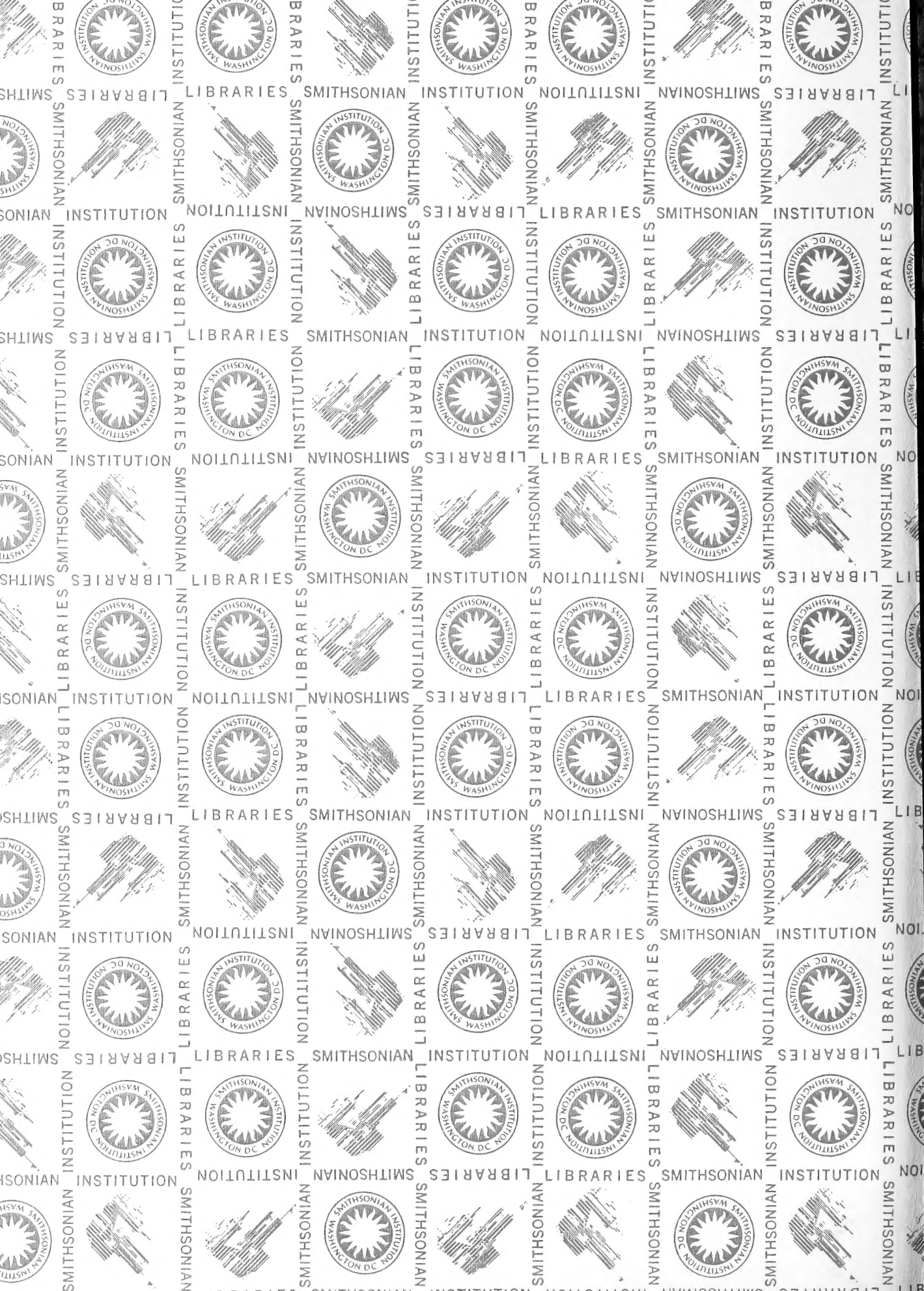
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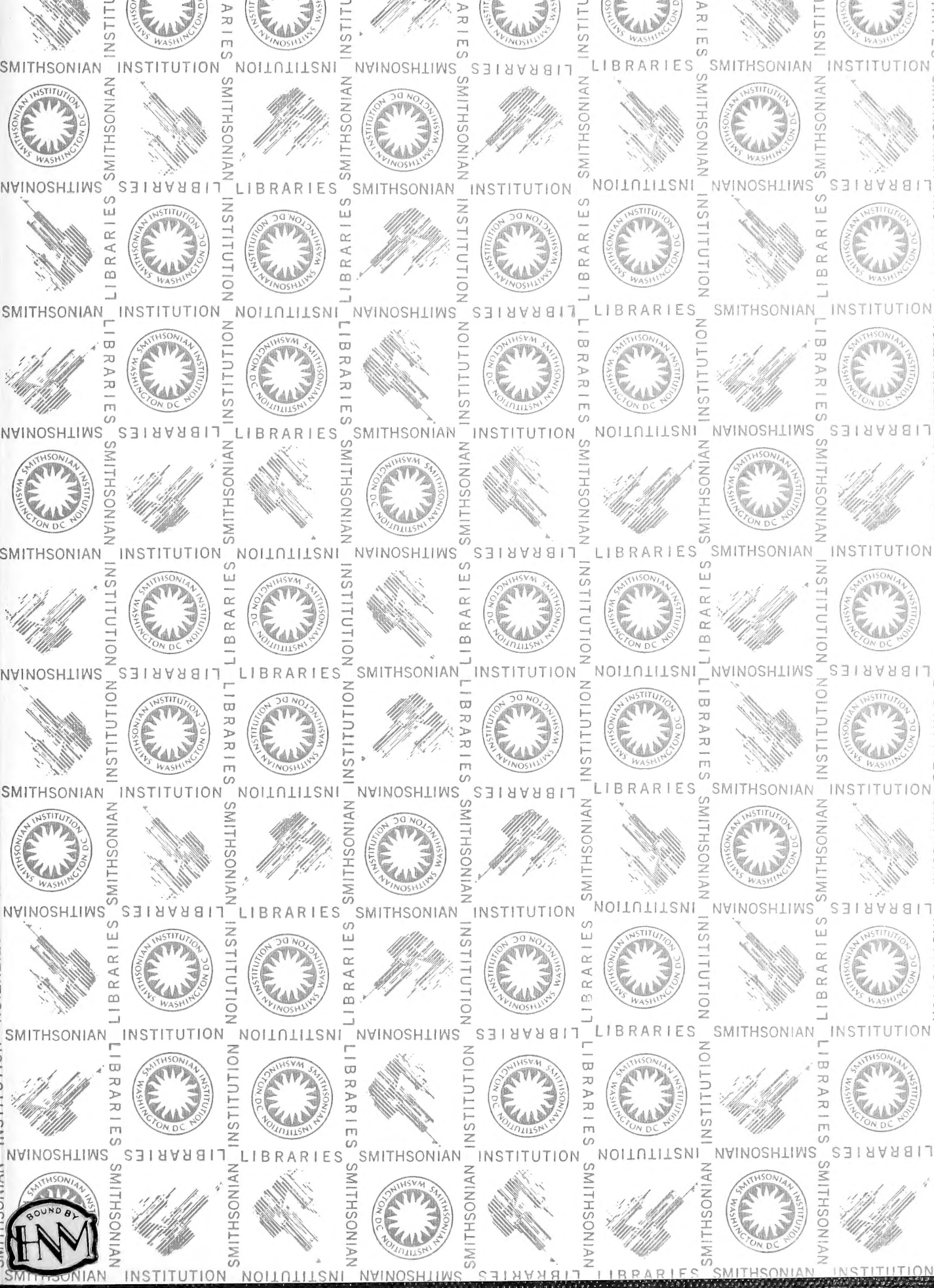
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